The Relationship of Fee Structure in Engineering Offices and Design Deficiency

by

Mohammad Mahmoud Abolnour

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

December, 1994

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خلاصة البحث

إسم الطالب الكامل : محمد محمود أبو النور
عنوان الدراسة : العلاقة بين مكونات اتعاب المكاتب الهندسية والاخطاء التصميمية .
التخصص : هندسة وأدارة التشييد .
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يعتقد كثير من أفراد القطاع الهندسي في المكلة العربية السعودية أن هناك أزمة في جودة التصاميم الهندسية . ويستند هؤلاء في اعتقادهم على الخلافات المستمرة بين المالك والمصمم والمقاول من ناحية وعلى ضعف الابتكار والابداع في التصاميم من ناحية اخرى . ويعزو هؤلاء اسباب هذه الازمة إلي عدم وجود القواعد التنظيمية الكافية لمزاولة مهنة الاستشارات الهندسة في المملكة السعربية السعودية وعلى راسها عدم وجود حد ادنى لاتعاب المكتب الاستشاري .

يتناول هذا البحث العلاقة بين اتعاب المكتب الاستشاري وتكاليف تصحيح الاخطاء التصميمية . كما يتناول ايضا تحديد أهم عناصر المكتب الهندسي التى لها علاقة مع هذه الاخطاء التصميمية . وقد قام الباحث بجمع المعلومات اللازمة عن طريق المقابلة الشخصية مع عينه عشوائية من المكاتب الهندسية الموجودة في منطقة الدمام ، بالاضافة الى المقاولين المنفذين للمشاريع المختارة .

وقد خلص البحث إلي أن اتعاب المكتب الهندسي تتناسب تناسبا عكسيا مع تكاليف تصحيح الاخطاء التصميمية . كما خلص ايضا الى أن االمهندسين المعماريين والكهربائين هم أكثر تخصصات المكتب الهندسي علاقة مع الاخطاء التصميمة .

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن
الظهران ، المملكة العربية السعودية
التاريخ ديسمبر ١٩٩٤م

THESIS ABSTRACT

MOHAMMED MAHMOUD ABOLNOUR
THE RELATIONSHIP OF STRUCTURE IN ENGINEERING OFFICES WITH DESIGN DEFICIENCY
CONSTRUCTION ENGINEERING AND MANAGEMENT
DECEMBER, 1994

In Saudi Arabia there is a strong belief among members of the construction profession that the quality of architectural design is in crisis. Continuous legal disputes among construction parties and the lack of creative ideas in design are some symptoms of the design quality problem. It is believed that one important reason for this quality problem is the lack of regulations which govern design quality which impact the minimum fee level for design services.

In light of this concern, this research aims to determine the relationship between design fee and design deficiency. It also aims to determine the design office components that contribute to controlling design deficiency.

To achieve these aims sixty projects were selected from twenty design offices in the Dammam metropolitan area. The required data for the research were collected by personal interviews with the professionals in the design offices and the contractors.

The research analyzes the collected data using statistical procedure. The analysis reveals that design fee has a nonlinear inverse relationship with design deficiency. The most important components that contribute in controlling design deficiency are the architects and electrical engineers in term of number of staff and experience.

To obtain a comprehensive coverage of the quality problem the research not only depended on statistical analysis, but also on the opinion of professionals in the field. Based on the research results and professional opinions the research suggests a system for a minimum design fee regulation.

CHAPTER ONE

INTRODUCTION

In Saudi Arabia there is a strong belief among members of the construction profession that the quality of architectural design is in crisis. One of the symptoms of this crisis is the continual legal disputes among contractors, owners, and design professionals. Other symptom are the lack of creative ideas in design. These symptoms have become very clear to the public in the last decade especially in small and medium sized projects.

Although the problem of lack of design quality is worldwide, it is more severe in the context of the construction industry in Saudi Arabia, due to many reasons which may not present in other countries. These reasons include:

1- The lack of regulations which govern the minimum fee level for design services makes some design offices lower their design fees, even below the break even point, in order to take jobs. Consequently, design offices try to cut corners in the design process resulting in less time for idea creation, less time for project review, fewer drawings, insufficient or incorrect construction details, fewer experienced staff, less in-house specialization, and less engineering equipment.

2- The absence of a system that organizes and unifies project documents in order to simplify the process of understanding and reviewing these documents. Consequently, each design office selects an international system that is compatible with the employees, the nature of the project, and the clients. This inconsistency leads to a higher probability of making mistakes, more wasted time and effort and a lower rate of experience acquisition.

3- The absence of building codes and regulations unifying the units of measurements for construction, for example, using the French or the English system in all construction-related disciplines . As a result, each office chooses whatever measurements suit its work conditions, or may choose different measurements for the same project. This situation exists because each design office mostly follows the measurements that its employees are used to in their home countries, and since each office has its own policy in recruitment of its employees, this variation of systems becomes a fact of life. Moreover, manufacturers and vendors also use other measurements than those of the design offices in their products and shop drawings, according to the origin of their technology. This variation of systems leads to difficulty in integrating all the project documents, conflicts and omissions, difficulty in controlling and tracking construction and design deficiencies, difficulty in talking the same language among the construction parties and difficulty in defining responsibility for deficiencies.

4- The lowest bidder method is the procedure used to select design professionals in most construction projects in Saudi Arabia. Many construction professionals consider this method the most harmful method to design quality (Manuals 1988).

5- The absence of engineering codes that organize the design profession. For example, fire prevention specifications, reinforced concrete specifications, and electrical work specifications.

The problem of design quality is complex and has so many diverse aspects that they cannot be tackled all at once in one thesis. It needs a collective effort from all construction parties. This research will, thus concentrate on one aspect of the problem, namely, the absence of minimum design fee regulation and its relation to the design deficiency.

1.1 Research Objectives

The main objectives of this research are to examine the relationship between design fee and design quality; and to determine the components of the design office structure that correlate to design deficiency.

1.2 Significance of the Study

There is no study that has dealt with the subject of the relationship between design fee and design deficiency in the local construction industry in Saudi Arabia. Although this study is limited to some offices in Dammam metropolitan area, the results could be use as guidelines in the context of Saudi Arabia. The results of the research shall benefit the following parties:

1.2.1 Clients

The study helps clients to :

1. Realize the impact of design fee on project quality.
2. Establish some criteria other than design fee for evaluating design offices.
3. Anticipate the return on money paid for design services.
4. Determine the most feasible design fee in terms of total quality costs.

1.2.2 Design Offices

The study aids offices to:

1. Improve their design quality by improving the controlling components in their offices.
2. Compare their performance with the performance of other design offices in the consulting field.
3. Determine the minimum fee they should charge for their design services.
4. Recognize the impact of their design quality on the project cost.

1.2.3 Contractor

The study helps contractors to:

1. Predict the volume of changes before signing the contract with the client by knowing the design office and the design fee.
2. Maintain their reputation by dealing only with the offices that are expected to produce quality projects.

1.2.4 Municipalities and Regulatory Agencies

the study helps municipalities to:

1. Recognize some aspects of the design quality problem as they occur in the construction field.
2. Determine the areas that need to be improved in local consulting practice.
3. Understand the benefits of suggested recommendations deduced from the professional's opinions and research results for solving the design quality problem.
4. Determine the value of the minimum design fee that reveals the least design deficiencies.
5. Survey the opinions of the related professionals on the quality problem.
6. Build a data base of local performance in term of design fee, design deficiency, change order, and owner change order.

1.2.5 Academics

1. Enrich local literature with significant data about the local consultant practices.
2. Point out other problematic areas for further research.
3. Measure the quality performance of local consultant offices.
4. Explore some dimensions of the design quality problem, namely design deficiency.

1.3 Scope

1- The study is limited to the Dammam metropolitan area.

2- The scope of the research is limited to all building projects except small villa projects; in order to avoid familiarity of the design staff with the project type. However, the research includes medium size villas which cost more than eight hundred thousands Saudi Riyals.

3- The study is limited to the projects which have been constructed within the last ten years in order to minimize as much as possible the change in the construction industry in term of technology, materials, and cost.

4- Contractors with good filing systems and proper data records are to be targeted in the sample as much as possible.

1.4 Organization of the Thesis

The research aims to explore two issues namely: the relationship between design fee and design deficiency and the determination of the office structure components that contribute most to controlling design deficiency. The thesis is organized into the following chapters.

Chapter one : Introduction

Introduction of the design quality problems in local practice. Determination of the symptoms and causes. Definition of the research objectives, significance and scope.

Chapter Two : Literature Review

Definition of design quality and the related terms namely: design, quality, design office, engineering consulting services, deviation and change order. Determining the methods of measuring design quality. Analysis of the Eastern Province's engineering consulting industry. Identifying the methods for selecting design offices locally and internationally.

Chapter Three : Research Structure

Detailed description of the core of the research is ordered starting from the data collection and ending with the conclusion.

Chapter Four : Data Collection

Definition of the required data in terms of their source and characteristics. Determination of survey technique, sample size and procedures for selecting the sample. Construction of the questionnaires and coding the collected data.

Chapter Five : Data Analysis and Results

To achieve the aims of the research, the collected data went through two sets of analysis. The first set depends on a regression analysis between design fee and design deficiency. The resulting charts between design fee and both design deficiency and change order are analyzed. The second set depends on running a canonical correlation analysis between design deficiency and office structure components to determine components which contribute the most to controlling design deficiency.

Chapter Six : Market Performance

The first aim of this chapter is to evaluate the general performance of the consulting market in the Eastern Province in terms of design fee and each of the office components that contribute to controlling design deficiency cost as evidenced by the results of the canonical correlation analysis. This evaluation will determine the most problematic factors that the consulting offices suffers from. The second aim is to discuss the field professional's opinions to obtain a comprehensive coverage of the other factors that are believed to be affecting design quality.

Chapter Seven : Conclusion And Recommendations

Brief description of the research work in order to achieve the required objectives. Proposal of minimum design fee regulation and suggested procedure for implementation in the local practice.

CHAPTER TWO

LITERATURE REVIEW

In order to achieve its research objectives, the study presents the following discussion of related issues:

1- Terminology
2- Methods to measure design quality
3- Procurement of design services in international and local practice
4- Minimum design fee regulation
5- Analysis of the Eastern Province engineering consulting industry

2.1 Terminology

The Engineering Council in London (1986) defined the term "design" which was presented by McGeorge (1988, pg. 350) as :

"an iterative process with each iteration aimed at increasing the level of information in order to improve the decision making. Coordinating the collection, processing, storage and transmission of information is essential for effective design. Existing information flows should be analyzed to identify bottlenecks and remove them."

The Quality Management Task Force (QMTF) of the Construction Industry Institute developed a glossary of quality terminology which was presented by Burati and Farrington (1987, pg. 35). One key definition used in the glossary is for the term "quality".

"Quality is defined as 'conformance to established requirements' by avoiding dealing with degree of goodness or satisfaction, this definition provides a basis for measurement, i.e., the requirements are either met or not met."

"Quality" is also defined as "meeting the requirements of the owner, design professional, and constructor as specified by contract, while complying with laws, codes, standards, regulatory rules, and other matters of public policy" (Manuals 1988, pg. 1-2). In other words, "quality design" is the design that is effective (serves its purpose) and compatible with the best possible economy and safety.

A related term to "design quality" is "deviation". The term indicates that a product or result that does not fully conform to all specification requirements does not necessarily constitute an outright failure (Davis et al. 1989). Deviation includes changes to the requirements that result in rework, as well as products or results that do not conform to all specification requirements, but do not require rework.

In this regard, "change order is a written agreement between the owner and the contractor authorizing an addition, deletion, or revision in the work and/or time of completion within the limits of the terms of the construction contract after it has been executed. It is a specific type of the contract modification that does not go beyond the general scope of the existing contract" (Fisk 1988, pg. 433).

Another related term is "design office" which can be defined as :

"The quintessential information processing system; information drawn from a host of sources-the market place, design codes, technical literature, the client's terms of reference, the knowledge and experience of the designers- is processed into something which is (hopefully) elegant, useful, and economical (McGeorge 1988, pg. 354).

2.1 Methods of Measurement

For measurement purposes, "design quality" is loosely defined in terms of output of goods or services for a given unit amount of resource input (capital, labor, knowledge, and material) because of two reasons, namely: design quality does not have an absolute value for measurement, but only comparative value with the past or with other products; secondly, it is difficult to measure what it is desired to know (Construction Industry Institute 1986). Lots of attempts have been made in this regard, trying to measure design quality in construction projects. One approach is to calculate the project cost after construction and this will be a good indicator of the project quality compared with identical projects (McGeorge 1988). Although this approach is convenient, the author sees it has its limitations namely:

1- This measurement cannot be used during the design process or directly after finishing the design documents, in other words, knowing after the fact.

2- This measurement ignores some important issues affecting design quality like project impact on surrounding environment .

3- This measurement does not take into consideration costs like operating costs and maintenance costs.

Another approach, which is more comprehensive, tries to measure issues directly related to quality as follows (Manual 1988).

1- Meeting the requirements of the owner as to: function and appearance; completion on time and within budget; life cycle cost; operability and maintainability; environmental, health, safety, and human impact; and features.

2- Meeting the requirements of the design professional as to: defined scope, adequate budget, reasonable schedules, timely decisions by owner, interesting work for the staff, realistic risk sharing, reasonable profit, a satisfied client; and a finished project which result in positive recognition and recommendation for future work.

3- Meeting the requirements of the constructor as to: a well-defined set of plans, specifications, and other contract documents, a reasonable schedule, timely decisions by the owner and design professional, fair treatment, realistic risk sharing, reasonable profit, a satisfied owner, and positive recognition and recommendation for future work.

4- Meeting the requirements of regulatory agencies as to: public health and safety; environmental consideration; protection of public property, including utilities; and conformance with applicable laws, regulation, codes, standards, and policies.

This approach is better than the first one in terms of coverage of all aspects of quality, yet the author sees that it has its limitation in practical application such as:

Although some of the quality elements can be measured with proper scales like conformance to applicable codes, completion on time, and up to standard, completed contract documents, and reasonable profit for the designers; some of the quality elements are subjective and can not be measured on a reasonable scale like owner satisfaction and appearance.

The third approach is to develop a system to evaluate the quality management activities in both the design and construction phases, then to try to determine the cost of poor quality in design and construction. This approach was devised by Kent Davis in 1987 on five construction projects. He developed a system (QPTS, Quality Performance Tracking System) that divides quality management activities into eleven activities in the design phase and fourteen activities in the construction phase. This system includes a cost coding scheme compatible with the state of the art cost and schedule coding system in design and construction, to record cost of deviations. Davis recommended that the QPTS developed in this study should be considered as a preliminary model and that a great deal of work remained to be accomplished. Davis listed several areas that are worthy of research. They include:

"1- consideration of quality cost tracking of activities other than that of the construction process (preplanning, procurement, start up, operation, and disposal);

2- consideration of what portions of permit and liability costs should be considered quality costs;

3- development of a system to track impact costs;

4- study of the implementation costs and the cost effectiveness of the refined QPTS; and

5- study of the reliability of information generated by the QPTS."

In addition to previous shortages that made the study of Davis incomplete in terms of covering all aspects of quality in design and construction, the author sees the two prerequisite conditions suggested by Davis as necessary for the use of QPTS, make the implementation of this system very difficult, if not impossible, in the context of Saudi Arabia. These conditions are:

1- The study states that the requirements for the design and construction are clearly stated beforehand, but this is not the case for most construction projects in Saudi Arabia (Al-Shoaibi 1409h).

2- The study states that an adequate cost and schedule is in place. This clause makes the application of this approach very difficult in the construction practice in Saudi Arabia, due to the non-availability of such a cost and schedule coding system in most of local design offices.

The three approaches to measure "design quality" try to measure it as one discipline. However, there are other studies that take design deficiencies, being one facet of the discipline, as a measurement for design quality.

Design deficiency, in this context, is defined as "any deficiency in the drawings and / or the specifications which results in a facility which will not adequately perform its intended mission " (Lutz et al. 1990, pg. 297). Most design deficiencies can be categorized as one of the following three types (Lutz et al. 1990):

1- Contract document conflict: discrepancies between drawings and specifications.
2- Interdisciplinary coordination errors: conflicts or interference problems between structural, mechanical and electrical.
3- Technical compliance discrepancies: non adherence to the appropriate design guidelines, technical specifications and building codes.

Ideally, if there is no design deficiency four parties are satisfied, they are :

1- The owner;
2- The building codes and regulations;
3- The contractor;
4- The design professional.

The owner is satisfied during the process of design through his meetings with the design professional. Building codes are satisfied through the review process between the municipality and the design professional till the project is approved. The contractor and the design professional are satisfied when there are no deficiencies in the construction documents.

One of the studies which adopted the approach of design deficiency as a measurement for design quality was conducted by Burati and others in 1992. They undertook field experiments to collect quality deviation data from nine fast-track industrial construction projects. The data was collected after the construction phase of the projects to identify the direct costs associated with work including redesign, repair, and replacement. Analysis of the data indicated that deviations on the projects accounted for an average of 12.4% of the total project costs. Furthermore, design deviations average 78% of the total number of deviations, 79% of the total deviation costs and 9.5% of the total project cost. The construction deviation average was 16% of the total number of deviations, 17% of the total deviations costs, and 2.5% of the total project cost. These values are conservative because they consider only direct costs, but they are indications of the impact of design quality on the project total costs.

In addition, other studies (Kirby 1988; Morgen 1986) have identified the three major causes of the contract modifications as being: (1) Design deficiencies; (2) user requested changes; and (3) unknown site conditions. These studies have also revealed that 56% of all contract modification are to correct design deficiencies.

Out of the previous methods, measuring design quality by measuring one of its related aspects like design deficiency seems the most practical method to implement in the context of Saudi Arabia. Therefore, this research adopts this method for measuring design quality in Eastern Province design offices.

2.3 Procurement of Design Services in International and Local Practice.

2.3.1 International Practice

Selecting the right design professional is the first step to having quality design. It determines a minimum level of project quality from the very beginning. There are three methods for selecting a design professional (Manuals 1988). One method is based on the professional qualifications. The second is based on the two-envelope system, while the third is based on the price-bidding.

Out of the three methods for selecting the design professional, the first is considered by international standards to be the best. In this method, design professionals submit their statement of qualifications in response to an owner's invitation for a specific project. The responses are evaluated by the owner according to previously announced selection criteria. After selecting the design professionals on the basis of qualifications, contract negotiations between them and the owner are initiated. During the negotiations, scope of services, schedules, compensation, and other contractual matters are defined, agreed upon, and documented in a written contract. If the owner and design professional are unable to reach agreement, then negotiations with the next most qualified design professional are begun (Manuals 1988).

The second method of selecting the design professional is the two-envelope system, which involves submission of a technical proposal in one envelope and a price proposal in a second envelope. "The second envelope is to be opened only after the design professional has been selected on the basis of his or her technical proposal. The second envelope is then opened and used for negotiation of contract terms" (Manuals 1988, pg. 22).

The third procedure is the selection by price bidding. Many studies have pointed out the disadvantages of using this system in the construction industry. DeFraites (1989, pg. 126) presented the following points as some of these disadvantages:

"1- an adversely relationship is established in which the design professional no longer represents the "best interest" of the owner, but only those interest of the owner that were specified in the bid document scope of service.

2- the "low bidder" may lack the competence and experience required to design the project, further straining the relationship with the owner and resulting in an increase in total project cost.

3- for bids to be meaningful, a stringent scope of services must be developed, for which the owner becomes solely responsible. This results in (a) increased costs to the owner for the development of a stringent scope of service, even to the extent that a consultant is sometimes retained for this purpose; (b) a limitation on the evaluation of alternatives that could result in substantial reduction in the initial total project cost and life- cycle cost; and (c) the design professional looking for omissions, faulty conditions and inaccuracies upon which he may request change orders, once he is awarded the low bid.

4- if a poor or loose scope of service is provided by the owner for bidding purposes:(a) the design professional's bid prices often vary by 100% or more because each design professional has a different interpretation of the owner's intent; and (b) the owner usually discovers after the fact that the low bidder's intent is not what the owner expected.

5- time is money. Under the bidding process, owners often fail to realize the time required to develop a scope of services; request, receive, and evaluate proposals; resolve differences in concept between the bidder and owner; and enter into an agreement."

Out of the three methods for selecting design professional, the price bidding method is not recommended for use (Manuals 1988). Unfortunately, this method is the closest to the "walk-in" system that is mostly used in local practice for small and medium size projects in Saudi Arabia.

2.3.2 Local Practice

The "walk in " system is considered the most common system for selecting design professionals for small and medium size projects in the Eastern Province. The "walk-in" system means that the client enters the design office and asks for the price of design services for his project. He then compares the fees given to him with those of other offices. The best office to him is the one that offers the lowest fee.

This local system promises more serious disadvantages for the design quality than the price bidding process; especially in the absence of minimum fee regulations. The following disadvantages may occur:

1- The design professional is always pressured into giving a quick estimate based on an unclear and vague verbal project description. This results in an unstudied commitment and often leads to disagreement with the client.
   The design professional may either lose the job, or may take it with a price lower than the point of no profit. The design quality in this case is seriously jeopardized.

2- The client may often commit himself with only a verbal agreement to the design professional. This may encourage the owner to easily change his position on already agreed points or simply quit the office. Because of this scenario, the design professional may often not exert the required effort to produce quality design.

3- Verbal agreements often are accompanied by many change orders that create an unhealthy environment between the client and the design professional and lead to legal disputes.

In this context Al-Shoaibi (1409H.) has compared the fee level situation in Saudi Arabia with that of international minimum fee level for design services.

Charts (2.1, 2.2) highlight this comparison showing the marked discrepancy between local and international standards.

2.4 Minimum Design Fee Regulation.

Based on Al-Shoaibi (1409H.), chart (2.1) shows the minimum design fee charts in different countries in the world. The study of this chart reveals that the minimum design fee value varies according to the economic and employment conditions in each country. The main issue is that the existence of the minimum design fee regulation is necessary to organize professional practice in the country.

Also based on Al-Shoaibi (1409H.); that there is no minimum design fee regulation in the local practice of Saudi Arabia. Chart (2.2) shows the design fee of some local projects in comparison with the minimum design fee charts in Kuwait and Britain. This comparison indicates that the design fees in Saudi Arabia are much less than that in Kuwait and Great Britain.

Al-Shoaibi also stated that the free market system is the only system that exists and controls the design services pricing. In other words, there are no constrains that prevent design fee from going below certain fee limits. However, this should not be the case. The design product should not be treated like any other consumer goods due to the following differences (Al-Shoaibi 1409 H.):

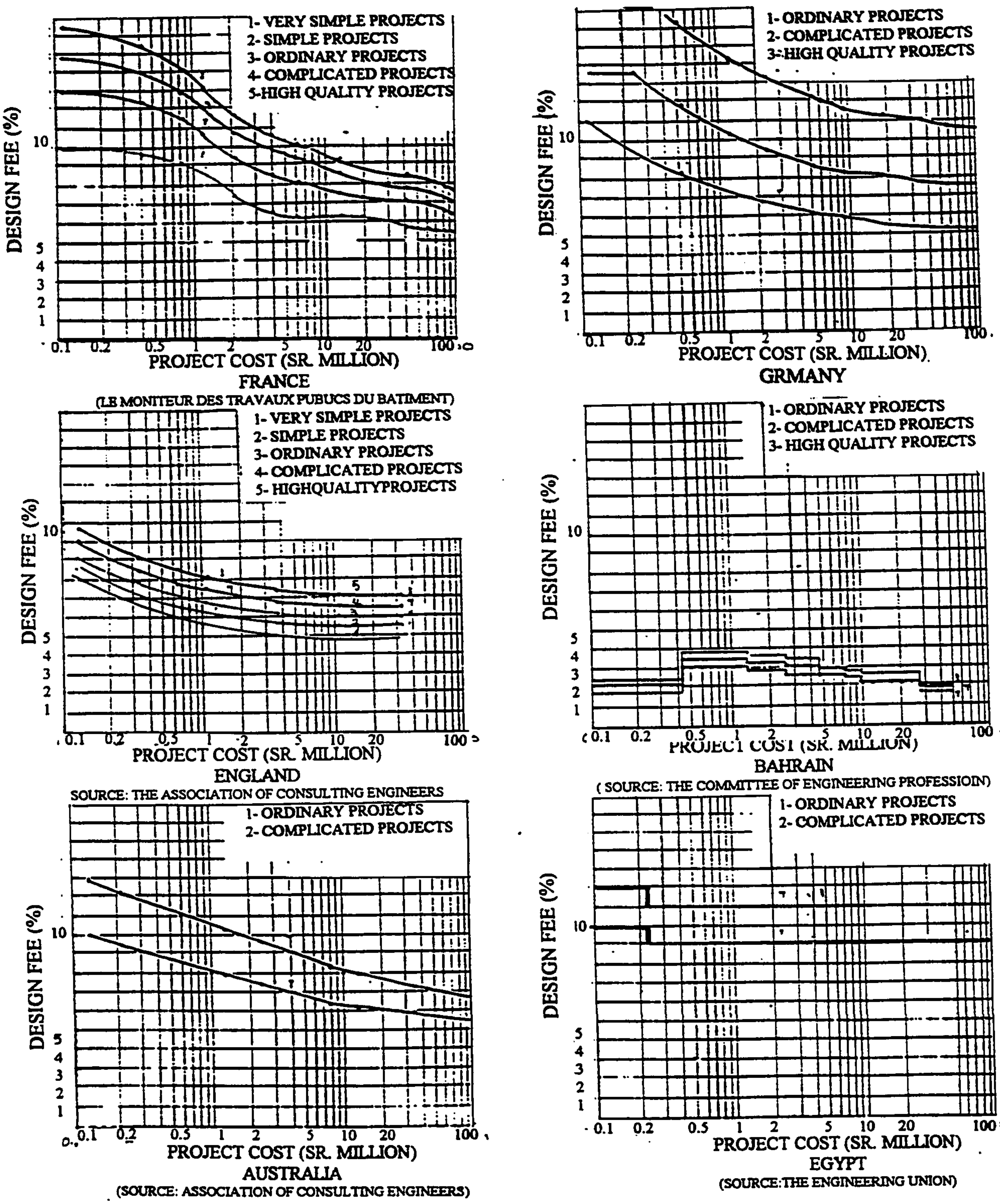
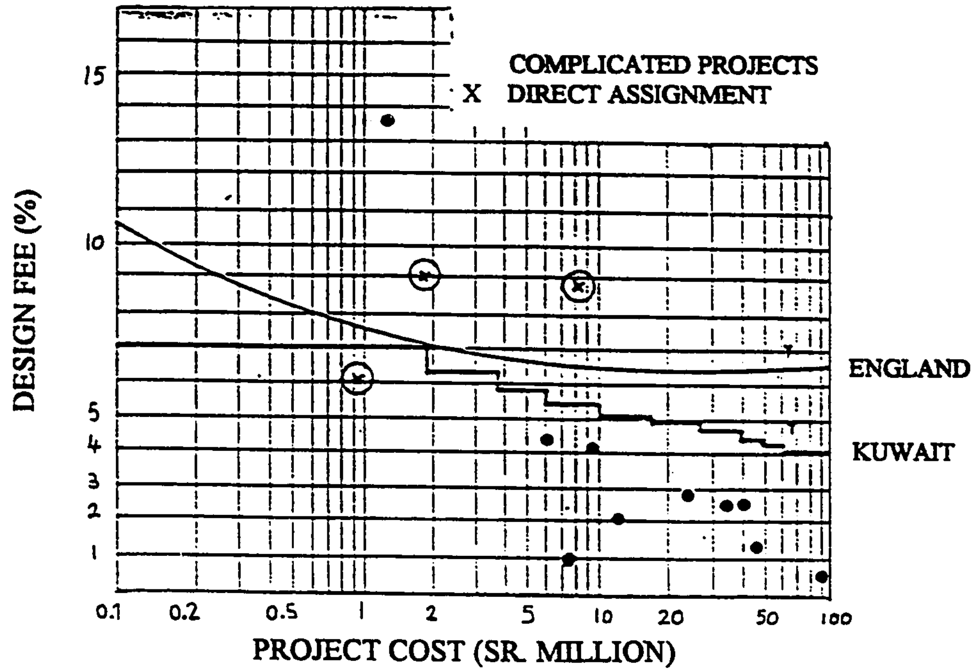


CHART 2.1.THE MINIMUM DESIGN FEE REGULATION CHARTS IN THE DIFFERENT COUNTRIES (AL-SHOAIBI 1409 H.)



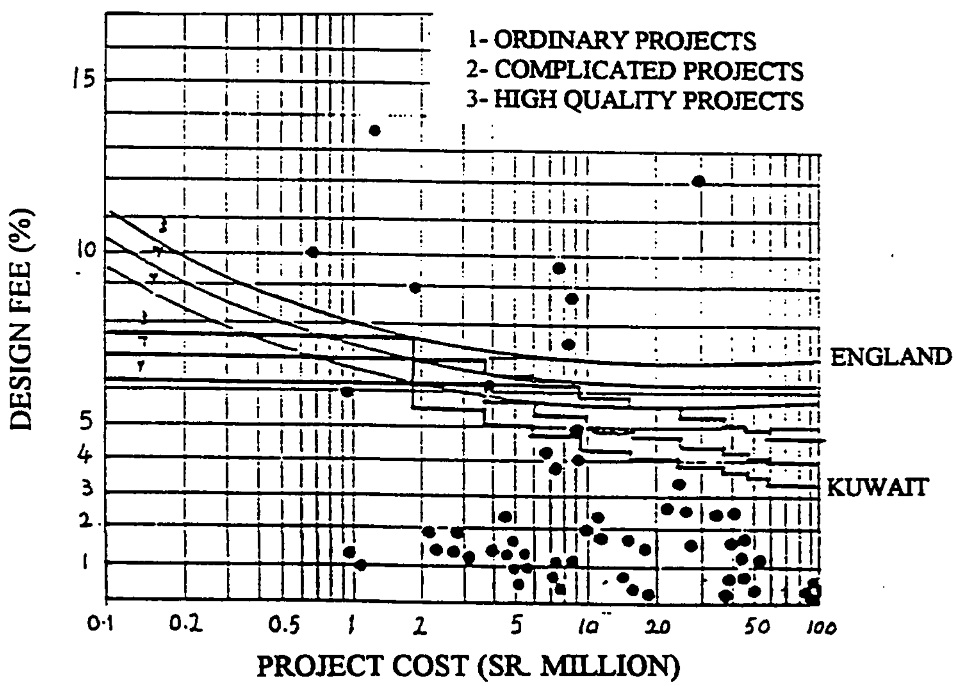


CHART 2.2. COMPARING DESIGN FEE IN SAUDI ARABIA WITH THE DESIGN FEE OF THE OTHER COUNTRIES (AL- SHOAIBI 1409 H.)
(THE POINTS REPRESENT THE DESIGN FEES IN SAUDI ARABIA)

a- unlike consumer goods, a design service product is unique and only made to fit certain human needs, environmental conditions and site conditions that differ from one project to another. So, the concept of repetition and mass production which is the main characteristic of consumer goods, is not available in design services products.

b- unlike consumer goods, the end product of the design services which is the built project, can not be seen, touched or used for months, and cannot be tested for functionality, comfort, safety, compatibility and effectiveness for years.

c- unlike consumer goods, the client is completely unaware of the degree of quality that the product has. In other words, the owner simply can not imagine the form, elevations and interior spaces of the designed project before construction.

d- unlike consumer goods, there are no available alternatives for the client to choose what suits him best. In other words the concept of comparing and selecting the best does not exist in design products.

Because of these differences between design products and other consumer goods, design fee can not be let to go below certain limits in the free market. There must be a regulation that controls this situation. This thesis will highlight this point and suggest a solution.

2.5 Analysis of the Eastern Province Consulting Industry

Basically, the data required for the research can be gathered by conducting a survey of the local A/E offices and the associated contractors who build their projects. It is known that there are 97 offices in the Eastern Province classified as shown in Tables 2.1, 2.2, 2.3.

Table (2.1) shows the distribution of the total number of design offices in the Eastern Province by different office category. It also shows that local A/E and consultant offices represent the majority of design offices in the Eastern Province.

Table 2.1. Number of Design offices in each category
(Engineering Committee 1411H.)

Consultant offices	Local A/E offices	Foreign A/E	Foreign consultants
42	49	2	4
43.3%	50.5%	2.1%	4.1%

Table (2.2) shows these design offices in the major cities in the Eastern Province. The table reveals that most of the design offices lie in the Dammam metropolitan area (Dammam, Khobar, Dhahran and Qatif).

Table 2.2. Number of Design offices in each city
(Engineering Committee 1411H.)

Hassa	Jubail	Khobar	Dammam	Dhahran	Qatif
13	3	26	40	5	10
13.5%	3.1%	26.6%	41.2%	5.2%	10.4%

Table (2.3) shows the distribution of each type of design offices in the major cities of the Eastern Province.

Table 2.3. Number of Design offices by each city and category
(Engineering Committee 1411H.)

Type	Hassa	Jubail	Dammam	Khobar	Dhahran	Qatif
Consultant offices	8	1	17	14	1	1
A/E offices	4	2	20	11	3	9
Foreign A/E	1	0	1	0	0	0
Foreign consultants	0	0	2	1	1	0

By studying the previous tables, this study found that Dammam metropolitan area is a region typifies the characteristics of the consulting industry in the Eastern Province due to the following reasons :

1- 83.5% of the total number of engineering offices are located within its area.

2- All types of engineering offices are found in the area which is not true for other areas.

3- The area has an abundance of all sizes of engineering offices unlike the other areas like the Al-Hassa area (Al-Hofuf and Al-Mobaraz).

CHAPTER THREE

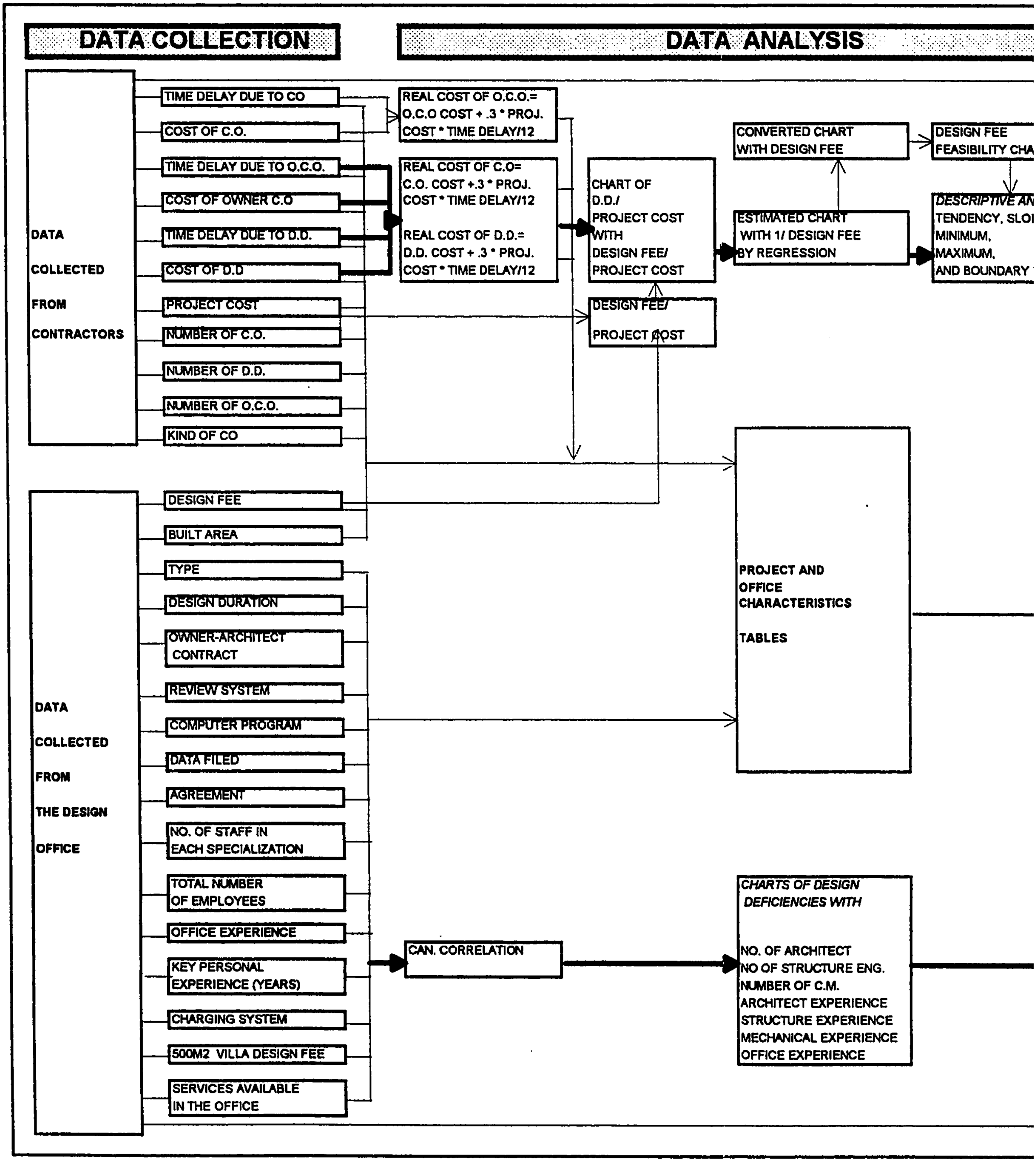
RESEARCH STRUCTURE

The research structure can be summarized as shown in chart (3.1). It starts with collecting the required data from two main sources; namely, the selected consultant offices and the contractors who build their respective projects. The research classifies the collected data into two groups; namely, project characteristics data and office characteristics data. The first group includes project data such as type, number, cost and time delay of changes. The second group includes the office characteristics data such as: number of staff in each specialization, staff experience and charging system.

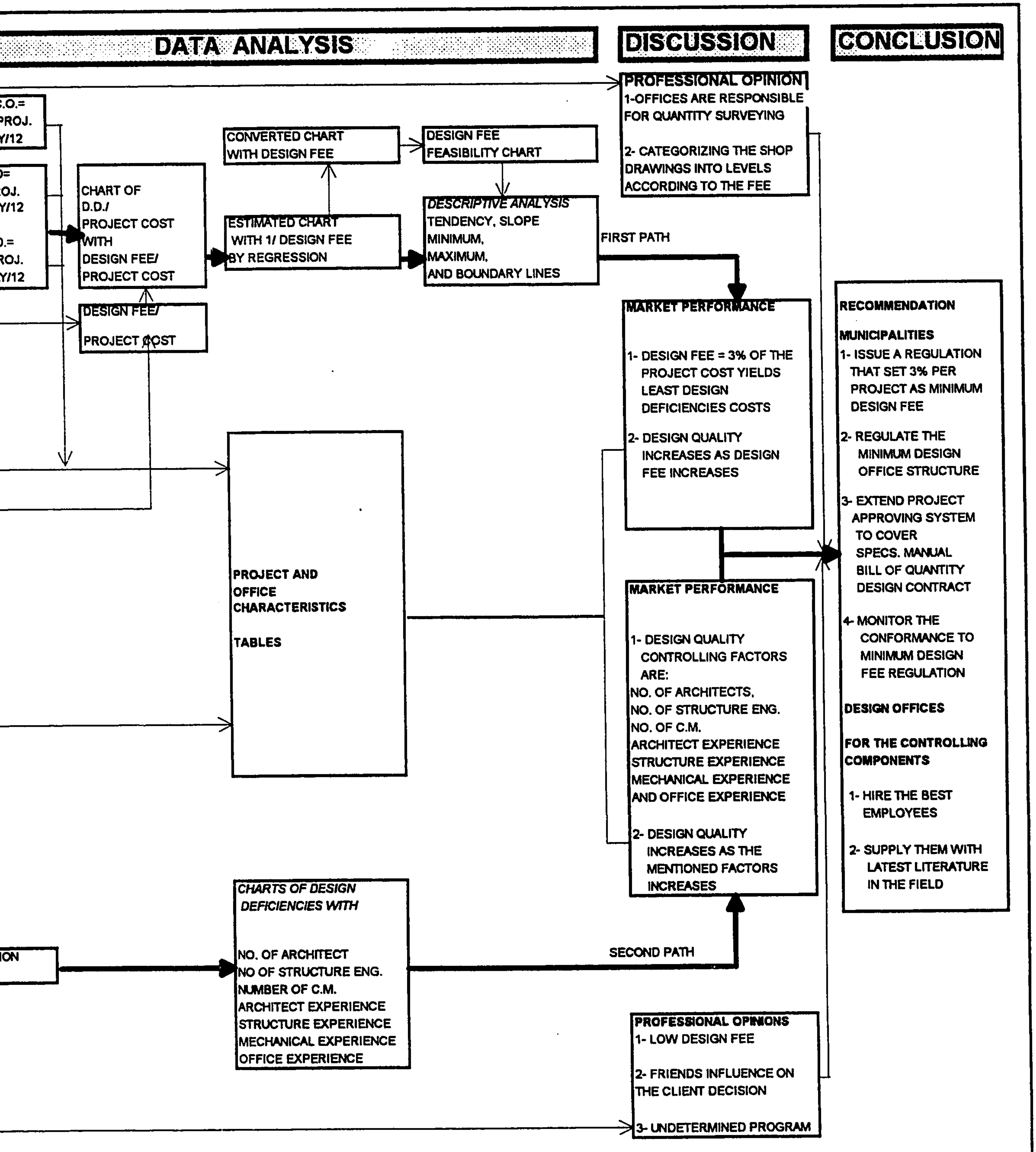
Project characteristics data are used to answer the first part of the research question i.e., the relationship between design fee and design deficiencies. Office characteristics data are used to answer the second part of the research question i.e., the design office structure components that contribute to controlling design deficiency.

To achieve the first objective, a regression model is used to relate design deficiency and design fee. The resulting curve from the regression is analyzed to describe the relation. To achieve the second objective, office characteristics data are processed through canonical correlation analysis to determine the most correlated office components. Frequency charts of the average design fee factor and the resulting office factors are then studied to determine the most problematic factors that the local consulting industry suffers from.

CHART (3.1) RESEARCH STRUCTURE PL



ART (3.1) RESEARCH STRUCTURE PLAN



Finally, the research ends with a conclusion of the results and series of recommendations based on the previous results along with the contractors and designers opinions of the design quality problem.

In light of the above, the research is divided into four parts namely: data collection, data analysis, discussion of the results and conclusion.

CHAPTER FOUR

DATA COLLECTION

Research data is derived from design offices and the contractors who build their projects. The study identifies twenty design offices and three projects for every office as a sample size. The required data are collected by personal interviews with personnel in these design offices and the contractors of the projects.

4.1 Definition of the Required Data

Two groups of data are required to define the relationship between design fee and design deficiency. The first group includes all change order information such as type, number, cost and time delay; for both owner change order and design deficiencies, in addition to design fee for every project. The second group includes project support data, namely project cost and built area. This group is needed to unify project conditions order to validate the comparison between different projects. For example, the cost of design deficiencies for a twenty million SR. project is usually more than that of a one million SR. project. However, the design quality of the one million SR. project does not have to be better than that of the twenty million SR. project. Therefore, the comparison between design deficiency cost per project cost for the two projects is revealed as a better indicator of design quality.

A third group of data is required to define the office structure components that contribute to controlling design deficiency cost. This group includes data such as: number of employees in every specialization, experience of each key person in every specialization, total number of employees in the office, office experience in the field, variety of work undertaken previously, type of computer programs used in executing the projects, type of contract with client, type of agreement with owner, reviewing system and filing system.

Obviously, contractors are the main source of the first group of data. Meanwhile, design offices are the main source of the second and third group of data.

4.2 Technique of Field Survey

There are no studies that have tackled the research objectives, namely, the relationship between design fee and design deficiency and the office structure components that contribute to controlling design deficiency in the local construction industry. Therefore, the field survey is considered the main source of the research data. In this regard, the personal interview is the most suitable survey technique for the nature of the study because of the following reasons :

1- It minimizes the tendency to distort the data from the sample representative side.
2- It might lead the researcher to discover some hidden aspects of the research that enrich research quality.
3- Discussing the issue of design quality with the designers and contractors in interviews may address other problems that need to be researched.

Since there are 81 design offices and thousands of projects in the Dammam Metropolitan Area (Engineering Committee in Riyadh 1411 H.), the determination of the sample size should be relevant to available research time and objectives.

4.3 Population and Sample Size

Based on the research scope, the research population includes all engineering offices in the Dammam metropolitan area, a total number of 81 offices distributed as shown in Charts 4.1,4.2,4.3,4.4.

Selecting the sample size mainly depends on the following equation (Cochran 1982)

$$\mathbf{n_o = t^2\, pq / d^2}$$

$$\mathbf{n = n_o / 1 + (n_o / N)}$$

where

$\mathbf{n_o}$ is first estimate of the sample size,

t is value of the standard normal variant. From the tables, assuming confidence level is equal to 95% level = 0.05 and **t** =1.96

p is the proportion of the characteristic being measured in the target population.

q is equal to 1-p

pq is maximum when p = 0.5 and q = 0.5.

d is the precision

N = 81 which is the whole population of the design offices in Dammam metropolitan area (Engineering Committee 1991)

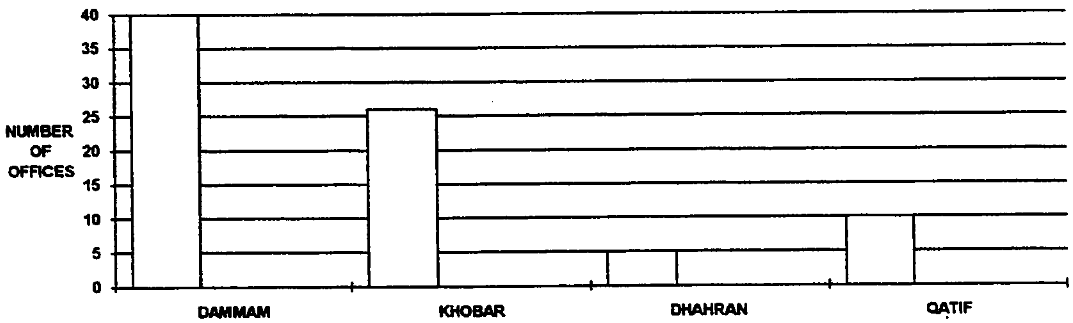


CHART 4.1
NUMBER OF OFFICES IN EACH CITY IN DAMMAM METROPOLITAN AREA
(ENGINEERING COMMITEE I 1411 H.)

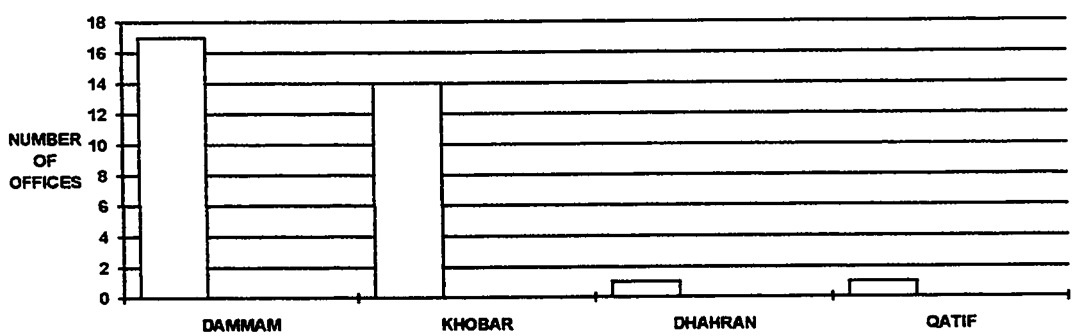


CHART 4.2
NUMBER OF CONSULTANT OFFICES IN EACH CITY OF DAMMAM METROPOLITAN AREA
(ENGINEERING COMMITEE 1411 H.)

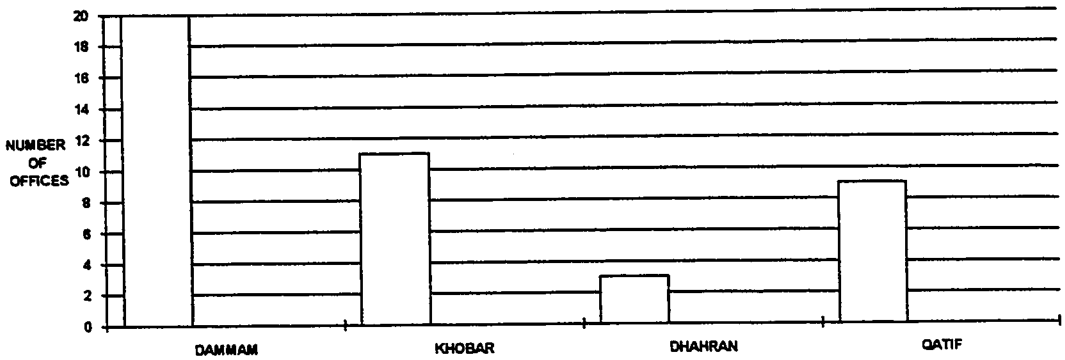


CHART 4.3
NUMBER OF A/E OFFICES IN EACH CITY IN DAMMAM METROPOLITAN AREA
(ENGINEERING COMMITEE 1411 H.)

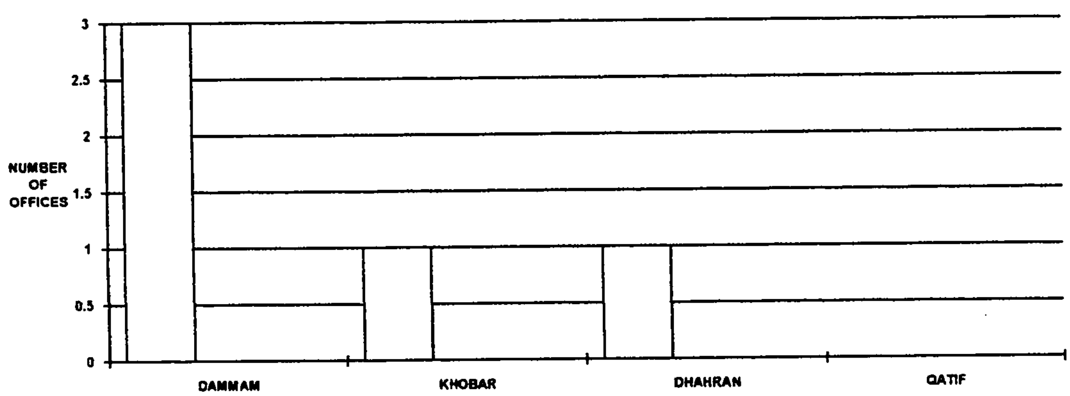


CHART 4.4
NUMBER OF A/E FORIEGN OFFICES IN EACH CITY IN DAMMAM METROPOLITAN AREA
(ENGINEERING COMMITEE 1411 H.)

n is the sample size.

$$n_o = (1.96)^2 \times 0.5 \times 0.5 / .001 = 960$$

First approximation, n_1 $= n_o/1+(n_o / N) = 960 / 1 + (960 / 81) = 74$

Second approximation, n_2 ....= 38

Third approximation, n_3 ....= 26

Fourth approximation, n_4 ....= 20

From the equation the research determines that the sample size is 20 offices out of 81 offices. The technique of selecting those 20 offices is designed to represent all variations in the population characteristics, namely, type and location. In terms of type classification, the twenty offices are divided into three groups according to the three types of offices namely; consultant, local design and foreign design offices. The number of offices in each group is determined as proportion of the number of offices in each type. Thus, the twenty offices are divided as follows:

eight consultant offices,

eleven A/E offices, and

one foreign A/E office.

In terms of the location classification, the number of offices in each of the previous groups is divided proportionally to the number of offices in each city.

For example, the consultant offices group is divided as follows:

four offices from Dammam city,

three offices from Khobar city, and

one office from both Dhahran and Qatif cities.

Having defined 20 offices as the sample size, the research seeks to determine the number of projects for each office. Taking one project as representative of each office might affect the accuracy of the data collected due to the probability of taking the worst or the best project designed by the office. In this case, the data collected do not fully represent this office in the sample. Therefore, the researcher selects a sample size of three projects from each of the 20 offices to avoid this problem. The technique of choosing these three projects depends on random sampling of all the projects in the office within the scope of the study.

4.4 Constructing the Interview Questions

In light of the previous considerations, there are two group of questions namely; design office questions and contractor questions.

Design office questions are divided into three parts. The first part includes questions about the office organization namely:

- Name and telephone number.
- Number of staff in each available specialization in the office namely; architecture, landscape, interior design, structure, mechanical, electrical, planning, construction management, drafting, value engineering, supervision and instrumentation.
- Experience of the key personnel in each of the previously mentioned specializations.
- Total number of employees in the office.
- Office experience in the field.

- Charging system.
- Design fee of 500 m. sq. villa.
- Services available in the office.

The question of design fee for an assumed 500 m. sq villa is considered for calculating the office design fee for selected projects if the office refuses to give the exact design fees for these projects.

The second part includes questions about the selected projects such as:

Project type
Location
Design date
Construction date
Built area
Design duration
Charged fee

Review system
Owner-Architect contract
Agreement type
Services furnished
Filing system
Computer program used.

The third part includes questions about the senior architect's opinion of the design quality problem namely:

Definition of design quality.
Measurements of design quality.
Reasons of design quality problem.
Suggestions for solving design quality problem.

Contractor questions are divided into two parts. The first part includes questions about the surveyed project namely :

Project cost
Construction duration
Number, cost and time delay of change orders.
Number, cost, kind and time delay of owner change orders.
Number, cost, kind and time delay of design deficiencies.

The second part includes questions about the contractors' opinions of the design quality problem.

4.5 Coding Research Data

The main policy followed in constructing the questions is that the answers should reveal the exact numbers where possible. In some cases, the use of the coding is a must for the following reasons:

1- The nature of the answers of being attributes such as in the questions about project type, location, review system, contract type, agreement, services furnished, filing system and computer program.

2- The respondent may only give ranges instead of the exact numbers because he considers the data as office secrets, such as the question of the charging fee of 500 m. sq. villa design.

3- The respondent may not know the exact number such as the question of design date and construction date.

In the previous cases the research allowed the respondent to give ranges that can be coded to a reasonable scale. Appendix 1, 2 shows the questions format for both the design offices and the contractor.

Project and office characteristics Tables 4.1 and 4.2 show the coding system for the collected data.

CHART (4.1). PROJECT CHARACTERISTICS TABLE

NAME	TYPE	LOCATION	DESIGN DATE	CONSTRUCTION DATE	BUILT AREA (METER SQUARE)	DESIGN DURATION (WEEKS)	REVIEW SYSTEM	OWNER- ARCHITECT CONTRACT	AGREEMENT	SERVICES	DATA FILED	USE OF COMPUTER PROGRAM	DESIGN FEE (THOUSANDS OF SR.)	PROJECT COST (MILLIONS OF SR.)	CONSTRUCTION DURATION (MONTHS)	NO. OF CHANGE ORDERS	COST OF CHANGE ORDERS (THOUSANDS OF SR.)	TIME DELAY OF C.O. (MONTHS)	NO. OF DESIGN DEFICIENCIES	COST OF DESIGN DEFICIENCIES (THOUSANDS OF SR.)	TIME DELAY OF D.D. (MONTHS)	NO. OF OWNER CHANGE ORDERS	COST OF O.C.O. (THOUSANDS OF SR.)	TIME DELAY OF O.C.O (MONTHS)	ELECTRICAL	MECHANICAL	REINFORCEMENT	PARTITION	PLUMPING	FINISHING	ADDITIONS	MISSING	DESIGN FEE PER PROJECT COST	REAL COST OF CHANGE ORDERS PER PROJECT COST	REAL COST OF DESIGN DEFICIENCIES PER PROJECT COST	REAL COST OF OWNER CHANGE ORDERS PER PROJECT COST
101	1	2	3	4	800	12	3	4	3	4	3	3	100	2.5	12	3	960	0	2	270	0	2	690	0	0	0	0	1	0	1	1	0	0.040	0.38	0.11	0.28
102	5	2	3	4	2000	12	3	4	3	4	3	3	450	2	12	2	600	0	1	300	0	1	300	0	1	0	0	0	1	1	0	0	0.225	0.30	0.15	0.15
103	5	2	4	4	3000	12	3	4	3	4	3	3	350	5.5	12	1	120	0	1	0	0	1	120	0	0	0	0	0	0	1	0	0	0.064	0.02	0.00	0.02
201	2	2	3	4	3000	20	2	4	3	1	3	3	180	13	15	1	2000	0	1	0	0	1	2000	0	0	0	1	0	0	1	0	0	0.014	0.15	0.00	0.15
202	1	2	4	4	800	15	2	4	3	2	3	1	50	3	12	3	600	0	2	300	0	2	300	0	0	0	1	0	0	1	1	0	0.017	0.20	0.10	0.10
203	2	2	4	4	4000	25	2	4	3	1	3	1	200	15	15	4	1000	0	2	300	0	2	700	0	1	0	1	0	0	1	1	0	0.013	0.07	0.02	0.05
301	5	2	3	4	6000	18	2	4	3	2	3	1	150	7	24	50	9900	36	25	900	18	25	9000	18	1	1	1	1	1	1	1	0	0.021	1.86	0.35	1.51
302	2	1	3	4	1000	9	2	4	3	2	3	1	70	2.1	12	3	90	0	0	90	0	0	0	0	0	0	1	1	0	1	0	0	0.033	0.04	0.04	0.00
303	5	2	3	4	1000	9	2	4	3	2	3	2	90	3.5	18	20	2000	6	16	500	1	16	1500	5	1	1	1	1	1	1	1	0	0.026	0.65	0.16	0.49
401	1	4	1	4	16000	60	3	4	3	4	3	1	400	39	21	27	600	0	25	10	0	25	590	0	0	0	0	1	0	1	1	0	0.010	0.02	0.00	0.02

CHART (4.1). PROJECT CHARACTERISTICS TABLE (CONT.)

402	1	4	1	4	40000	60	3	4	3	4	3	1	400	37	18	12	1000	0	12	0	0	12	1000	0	0	0	0	0	0	1	0	0	0.011	0.03	0.00	0.03
403	2	4	1	2	4500	38	3	4	3	4	3	1	300	18	12	6	0	8	4	0	2	4	0	6	0	0	0	1	0	0	1	0	0.017	0.10	0.03	0.08
501	5	1	4	4	500	6	2	4	1	2	3	1	90	7	12	4	130	0	3	70	0	3	60	0	0	1	0	1	0	1	0	0	0.013	0.02	0.01	0.01
502	7	2	4	4	1250	8	2	2	2	2	3	1	45	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.015	0.00	0.00	0.00
503	1	1	4	4	1800	10	2	2	3	1	3	1	35	1.5	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.023	0.00	0.00	0.00
601	2	6	3	3	3000	62	3	2	2	4	3	3	335	13	18	10	2800	6	8	40	0	8	2760	5	1	1	0	1	1	1	1	0	0.026	0.29	0.003	0.27
602	8	3	3	4	18000	90	3	2	3	4	3	3	1800	18	18	3	650	0	3	0	0	3	650	0	1	0	0	1	0	0	1	0	0.100	0.04	0.00	0.04
603	2	6	3	4	6000	99	3	2	3	4	3	3	3000	24	20	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.125	0.00	0.00	0.00
701	7	1	3	4	7000	28	2	3	2	2	3	1	238	6.8	12	3	50	0	2	0	0	2	50	0	0	1	1	0	0	1	0	0	0.035	0.01	0.00	0.01
702	1	1	3	4	2700	12	2	3	3	2	3	1	140	3.5	24	2	60	0	2	0	0	2	60	0	1	0	1	0	0	1	0	0	0.040	0.02	0.00	0.02
703	5	3	3	4	11200	36	2	3	3	3	3	1	396	13	12	10	250	4	8	0	0	8	250	4	0	0	0	1	0	0	1	0	0.030	0.07	0.00	0.07
801	5	1	3	3	3000	12	2	2	2	3	3	1	200	4.2	12	4	250	0	2	150	0	2	100	0	0	0	0	0	0	0	1	1	0.048	0.06	0.04	0.02
802	5	1	3	3	3000	12	2	4	2	3	3	1	600	36	12	50	2000	2	30	800	0	30	1200	4	1	1	0	1	0	1	0	0	0.017	0.08	0.02	0.08
803	5	1	4	4	2000	15	2	4	3	3	3	1	150	2	12	4	80	2	1	30	1	1	50	1	0	0	0	1	0	1	1	0	0.075	0.07	0.03	0.04
901	2	2	4	4	2000	60	2	4	3	1	3	1	300	18	18	23	5000	5	19	1000	1	19	4000	4	1	1	1	1	1	1	1	0	0.017	0.34	0.07	0.27
902	5	2	4	4	4000	50	2	4	3	1	3	1	275	15	18	12	150	6	8	25	2	8	125	4	0	0	0	1	1	1	1	0	0.018	0.09	0.03	0.06
903	1	1	3	4	3800	55	2	4	2	2	3	1	200	6	15	4	200	0	2	40	0	2	160	0	0	0	1	1	0	1	1	0	0.033	0.03	0.01	0.03
1001	1	2	2	3	1000	16	2	4	1	2	2	1	40	2.8	12	6	300	3	30	200	2	30	100	1	1	0	1	1	1	1	0	0	0.014	0.14	0.10	0.05
1002	6	2	3	3	5000	12	2	4	1	1	2	1	25	5	8	2	150	8	1	50	3	1	100	5	1	0	1	1	0	1	0	0	0.005	0.13	0.05	0.08
1003	6	2	3	4	5000	20	2	4	2	1	2	1	60	10	24	20	500	8	8	300	5	8	200	3	1	1	1	1	0	1	0	1	0.006	0.15	0.09	0.06
1101	2	2	3	4	2700	12	2	4	2	1	2	1	35	2.5	8	0	600	0	0	200	0	0	400	0	0	0	0	0	0	0	0	0	0.014	0.24	0.08	0.16
1102	5	2	3	4	20000	12	2	4	2	2	2	1	40	6.3	11	4	130	2	2	30	1	2	100	1	0	0	1	1	1	1	1	0	0.006	0.05	0.02	0.03
1103	5	2	3	4	2400	10	2	4	2	2	2	1	40	0.6	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.067	0.00	0.00	0.00
1201	1	2	4	4	12600	10	2	3	2	1	2	1	40	2.5	12	6	250	0	0	250	0	0	0	0	0	0	1	1	0	0	0	1	0.016	0.10	0.10	0.00
1202	2	2	4	4	2400	8	2	4	2	2	2	1	15	2	14	2	50	4	0	50	4	0	0	0	1	0	1	0	1	0	0	1	0.008	0.08	0.08	0.00
1203	1	2	4	4	2500	8	2	4	2	2	2	1	45	2	11	2	250	2	1	125	1	1	125	1	1	1	1	1	1	1	1	0	0.023	0.15	0.08	0.08
1301	2	2	3	4	3000	72	2	3	2	2	2	1	240	13	18	35	1200	2	30	300	1	30	900	1	0	0	1	0	0	0	1	1	0.019	0.12	0.04	0.08
1302	2	1	3	4	900	6	2	4	1	3	2	1	10	3.3	12	44	800	0	40	100	0	0	700	0	1	1	1	1	0	1	1	1	0.003	0.24	0.03	0.21
1303	1	1	3	3	1000	6	2	4	1	2	2	1	16	4.5	18	50	1500	8	45	200	2	45	1300	6	0	0	1	1	1	1	0	1	0.004	0.43	0.07	0.36
1401	1	1	3	3	500	16	2	4	1	2	1	1	4	0.8	12	6	110	0	0	110	0	0	0	0	0	0	1	1	1	1	0	1	0.005	0.14	0.14	0.00
1402	1	1	3	3	550	12	2	4	1	1	1	1	4	0.8	12	2	160	1	0	160	1	0	0	0	0	0	1	0	0	1	0	0	0.005	0.21	0.21	0.00

CHART (4.1). PROJECT CHARACTERISTICS TABLE (CONT.)

1403	1	1	3	3	800	48	2	4	1	1	1	1	1	1.3	12	2	270	2	1	100	1	1	170	1	0	0	1	0	0	1	1	0	0.008	0.23	0.09	0.14
1501	1	2	3	4	1400	10	2	4	2	2	2	1	11	2	20	50	660	3	28	180	1	28	500	2	1	0	1	1	0	1	0	0	0.006	0.37	0.09	0.28
1502	6	2	3	3	225	25	2	4	1	2	2	1	60	6.5	12	4	0	8	2	0	3	2	0	5	0	1	1	1	0	0	0	0	0.009	0.10	0.04	0.06
1503	1	1	3	3	800	20	2	4	3	3	2	1	25	4	15	10	500	5	2	200	3	2	300	2	0	1	1	1	0	0	1	0	0.006	0.19	0.09	0.10
1601	1	2	3	4	1200	12	2	2	3	1	1	1	20	2	18	2	90	0	0	90	0	0	0	0	0	0	1	1	0	1	0	0	0.010	0.05	0.05	0.00
1602	7	2	3	4	1200	12	2	2	3	1	1	1	22	2.5	12	5	200	4	2	150	2	2	50	2	0	0	1	1	0	1	1	0	0.009	0.13	0.09	0.05
1603	8	2	3	4	900	12	2	2	3	1	1	1	20	4	12	8	400	0	4	200	0	4	200	0	0	0	1	1	0	1	1	0	0.005	0.10	0.05	0.05
1701	9	2	4	4	1700	24	2	4	1	3	1	1	25	3.3	18	12	450	4	4	300	3	4	150	1	0	0	1	1	1	1	0	1	0.008	0.19	0.13	0.06
1702	1	1	3	4	1200	8	2	4	1	3	1	1	20	1.7	26	90	150	6	60	50	4	60	100	2	0	1	1	1	0	1	1	1	0.012	0.16	0.08	0.08
1703	1	2	3	4	1200	8	2	4	1	2	1	1	10	3	30	4	1000	6	4	0	0	4	1000	6	1	0	0	1	0	1	1	0	0.003	0.41	0.00	0.41
1801	1	2	4	4	1000	6	2	4	2	2	1	1	12	1.7	12	5	420	0	2	220	0	2	200	0	0	0	1	1	1	1	1	0	0.007	0.25	0.13	0.12
1802	1	2	4	4	800	6	2	4	2	2	1	1	12	0.7	12	2	270	0	1	60	0	1	210	0	0	1	1	0	0	0	0	1	0.017	0.39	0.09	0.30
1803	1	1	4	4	500	12	2	4	2	1	1	1	10	0.5	12	3	120	0	2	20	0	2	100	0	0	0	1	1	0	1	1	0	0.020	0.24	0.04	0.20
1901	1	2	3	4	4E+05	12	2	4	2	2	1	1	120	17	18	20	2700	6	11	2000	3	11	700	3	0	0	1	1	0	1	1	1	0.007	0.23	0.16	0.08
1902	2	2	3	4	2400	3	2	4	1	2	1	1	45	5	12	50	900	3	10	500	2	10	400	1	0	0	1	1	0	1	1	1	0.009	0.22	0.13	0.09
1903	1	2	3	4	11000	6	2	4	1	1	1	1	120	3	12	20	200	7	12	100	3	12	100	4	1	1	1	1	1	1	1	1	0.040	0.15	0.07	0.08
2001	5	1	4	4	1200	6	2	4	3	1	1	1	45	1.5	12	8	500	0	4	300	0	4	200	0	0	0	1	0	0	1	1	0	0.030	0.33	0.20	0.13
2002	4	2	4	4	12000	4	2	4	2	2	1	1	30	1.2	12	20	300	0	4	50	0	14	250	0	0	1	1	1	0	1	1	0	0.025	0.25	0.04	0.21
2003	1	2	4	4	16000	4	2	4	2	2	1	1	35	1.8	12	1	85	0	1	0	0	1	85	0	0	0	1	0	0	0	1	0	0.019	0.05	0.00	0.05

TYPE
1 RESIDENTIAL
2 OFFICE BUILDING
3 MULTI-FUNCTION
4 INDUSTRIAL
5 SHOPPING
6 HOSPITAL
7 RECREATIONAL
8 EDUCATIONAL
9 RELIGION

LOCATION
1 DAMMAM
2 KHOBAR
3 HASSA
4 JUBAIL
6 RAS TANN.

DESIGN DATE
1 80-83
2 84-87
3 88-91
4 92-94

CONST. DATE
1 80-83
2 84-87
3 88-91
4 92-94

REVIEW SYSTEM
1 NO REVIEW
2 SAME TEAM
3 ANOTHER TEAM

CONTRACT TYPE
1 COST PLUS
2 MAN-HOUR
3 PERCENTAGE
4 LUMPSUM

AGREEMENT
1 VERBAL
2 BRIEF WRITTEN
3 DETAILED WRITTEN

SERVICES FURNISHED
1 DESIGN ONLY
2 DESIGN AND SUP.
3 DESIGN, SPECS. & SUP.
4 COMPLETE SERVICES

DATA FILED
1 JUST DRAWING
2 1+ MEETING MINUTES, FAXES
3 1+2 +TECHNICAL REPORTS

COMPUTER PROGRAMS
1 NO PROGRAM USED
2 AUTO CAD
3 INTERGRAGH

CHART (4.2). OFFICE CHARACTERISTICS TABLE

NAME	1	2	3	4	5	6	7
NUMBER OF ARCHITECTS	3	3	2	6	4	7	8
NUMBER OF LANDSCAPERS	0	0	0	1	1	0	1
NUMBER OF INTERIOR DESIGNERS	1	1	0	6	2	1	1
NUMBER OF STRUCTURAL ENGINEERS	6	2	3	5	2	15	2
NUMBER OF MECHANICAL ENGINEERS	4	1	0	4	1	9	1
NUMBER OF ELECTRICAL ENGINEERS	4	2	1	5	2	10	2
NUMBER OF PLANNERS	0	0	0	0	1	0	1
NUMBER OF CONSTRUCTION MANAGERS	4	1	0	13	0	19	2
NUMBER OF DRAFTSMEN	80	10	6	3	10	32	13
NUMBER OF VALUE ENGINEERS	0	0	0	3	0	2	0
NUMBER OF SUPERVISORS	4	2	5	10	5	35	1
NUMBER OF INSTRUMENTATION ENGINEERS	0	0	0	0	0	11	0
NUMBER OF EMPLOYEES	106	22	17	56	28	141	32
OFFICE EXPERIENCE (YEARS)	14	4	10	12	11	25	9
ARCHITECT EXPERIENCE (YEARS)	11	35	10	30	8	18	13
LANDSCAPER EXPERIENCE (YEARS)	0	20	0	30	8	0	15
INTERIOR DESIGNER EXPERIENCE (YEARS)	10	10	0	0	9	25	3
STRUCTURAL ENGINEER EXPERIENCE (YEARS)	15	7	20	17	15	23	12
MECHANICAL ENGINEER EXPERIENCE (YEARS)	20	8	0	22	8	25	20
ELECTRICAL ENGINEER EXPERIENCE (YEARS)	25	8	17	25	19	30	10
PLANNER EXPERIENCE (YEARS)	0	4	0	0	8	0	8
CONSTRUCTION MANAGER EXPERIENCE (YEARS)	15	10	0	30	0	25	0
DRAFTSMAN EXPERIENCE (YEARS)	15	5	10	10	5	15	14
VALUE ENGINEER EXPERIENCE (YEARS)	0	0	0	30	0	12	0
SUPERVISOR EXPERIENCE EXPERIENCE (YEARS)	15	0	10	25	25	20	10
INSTRUMENTATION EXPERIENCE (YEARS)	0	0	0	0	0	20	0
COST PLUS (%)	10	0	0	10	0	100	0
MAN-HOUR (%)	40	20	30	0	20	0	0
PERCENTAGE (%)	10	10	0	0	0	0	5
LNMPSUM (%)	40	70	70	90	80	0	95
DESIGN FEE PER 500 M.SQ. VILLA (CODE NUMBERS)	5	5	3	5	2	5	2
SERVICES FURNISHED (CODE NUMBERS)	11	7	4	11	4	12	5

CHART (4.2). OFFICE CHARACTERISTICS TABLE (CONT.)

8	3	1	0	1	1	1	0	1	6	0	4	0	18	10	16	6	0	8	5	23	0	6	25	0	7	0	0	65	0	35	3	5
9	3	1	0	2	1	2	0	1	8	0	1	0	19	12	20	0	0	7	15	15	0	10	17	0	7	0	0	100	0	0	3	5
10	3	0	0	3	0	1	0	0	3	0	0	0	10	15	23	0	0	13	23	29	0	0	15	0	0	0	20	0	0	80	2	5
11	3	0	0	3	1	1	0	0	6	0	0	0	14	6	6	0	0	10	13	20	0	0	15	0	0	0	0	10	0	90	2	5
12	2	0	0	2	0	1	0	0	5	0	0	0	10	17	16	0	0	25	0	5	0	0	16	0	0	0	0	0	0	100	2	6
13	3	0	0	2	0	1	0	0	4	0	0	0	10	13	15	0	0	15	0	12	0	0	6	0	0	0	0	0	0	100	2	5
14	3	0	0	1	0	0	0	0	0	0	0	0	4	6	14	0	0	10	0	0	0	0	0	0	0	0	0	0	0	100	2	2
15	2	0	0	2	1	1	0	0	2	0	0	0	8	9	9	0	0	16	18	18	0	0	0	0	0	0	0	0	0	100	2	5
16	1	0	0	1	1	1	0	0	2	0	0	0	6	9	17	0	0	17	12	7	0	0	12	0	0	0	0	90	0	10	2	5
17	2	0	0	2	0	0	0	0	4	0	0	0	8	5	4	0	0	10	0	0	0	0	15	0	0	0	0	0	0	100	2	6
18	3	0	0	1	0	1	0	0	3	0	0	0	8	1	13	0	0	6	0	0	0	0	4	0	0	0	0	0	0	100	2	3
19	3	0	0	2	1	1	1	0	3	0	1	0	12	11	3	0	0	5	4	2	0	0	3	0	3	0	0	0	0	100	1	6
20	2	0	0	2	0	1	0	0	4	0	0	0	9	2	14	0	0	6	0	22	0	0	14	0	0	0	0	0	0	100	2	5

1 **DESIGN FEE FOR 500 M.SQ. VILLA**

1 O-5000 SR. 2 5001- 15000 SR. 3 15001-30000 SR. 4 30001-45000 SR 5 More than 45000 SR.

2 **SERVICES AVAILABLE IN THE OFFICE**

FEASIBILITY STUDY. BASIC DESIGN SERVICE. SPECIFICATION. VALUE ENGINEERING. CONSTRUCTION MANAGEMENT.
QUANTITY TAKE-OFF. SUPERVISION. BID CONTRACT. SITE SELECTION. ENVIRONMENTAL STUDIES.
PROJECT BUDGETING. MARKETING STUDIES. PROGRAMING.

GIVING ONE POINT FOR EVERY SERVICE

CHAPTER FIVE

DATA ANALYSIS AND RESULTS

Based on the research structure plan, the analysis of the research data runs in two paths. The first analysis path aims to define design fee / design deficiency relationship. The second analysis path aims to determine the office structure components that contribute to controlling design deficiency.

5.1 The Relationship Between Design Fee and Design Deficiency

As mentioned in the literature review chapter, one of the approaches used to measure design quality is measuring design deficiency. This is because design deficiency is considered a main component of design quality. Therefore, the relation between design fee and design deficiency is a very good indicator of the relationship between design fee and design quality.

The analysis starts by regressing design fee per project cost values with design deficiency per project cost values for the sixty projects. The estimated model resulted from the regression is then analyzed to define the nature of the relationship between design fee and design deficiency.

Two important issues must be clarified before starting the analysis to deduce the relationship between design fee and design deficiencies in the local consultant practice. Firstly, some of the collected data must be converted into other forms in order to perform the analysis. In this regard, design fee, change orders, design deficiencies and owner change order can not be used in their abstract numbers as collected. This is because the analysis between different project sizes would reveal incorrect results that do not accurately describe the real relation between design fee and design deficiencies. Therefore the study unifies the selected projects by dividing project design fee, change orders, design deficiencies and owner change orders value on project cost. In this way the study eliminates the difference between the selected projects in order to run all kinds of analysis and comparisons between homogeneous data.

Based on the change order definition "a written agreement between the owner and the contractor authorizing an addition, deletion, or revision in the work and/or time of completion within the limits of the terms of the construction contract after it has been executed. It is a specific type of the contract modification that does not go beyond the general scope of the existing contract" (Edward 1988), the change order includes all changes that are issued to correct design deficiency and to perform owners' changes. Therefore, The following equations are true:

Cost of change orders = cost of design deficiencies + cost of owner change orders.

Dividing the cost equation by project cost retrieves another set of the equation :

Cost of change orders per project cost = cost of design deficiencies per project cost + cost of owner change orders per project cost.

Secondly, the cost of design deficiency does not represent all losses incurred by the owner. In practice, the owner incurs some other costs due to the time delay that results from correcting design mistakes. In this regard, the real cost of design deficiency is equal to the sum of direct costs of the design deficiency, which the contractor charges for the changes, plus indirect costs resulting from delaying project completion. A formula was developed to calculate the indirect costs of change orders based on the profits which would be expected to be gained by the owner if the project were submitted on time. Assuming the average annual profit for any project is equal to 15 % of the project cost. The developed formula is as follows :

Indirect costs = 0.15 x project cost x time delay in months / 12

Where:

0.15 x project cost is the estimated annual profit for the project.

Time delay in months / 12 is the time delay percentage.

Based on the previous equation

Real cost of design deficiencies = direct costs of design deficiency + 0.15 x project cost x time delay in months / 12.

Real cost of design deficiencies per project cost = (direct costs of design deficiency + 0.15 x project cost x time delay in months / 12) / project cost.

5.1.1 Design Fee Versus Design Deficiency

Chart (5.1) shows the relationship between design fee per project cost on the X-axis with the real cost of design deficiencies per project cost on the Y-axis for the sixty projects studied in the field survey. Theoretically, there are two projects that should be eliminated because of being clearly out-liers. The first project is approximately twice the maximum fee value and ten times the average design fee per project cost value. This design fee value makes the project a special case that does not represent design fee range in the local practice.

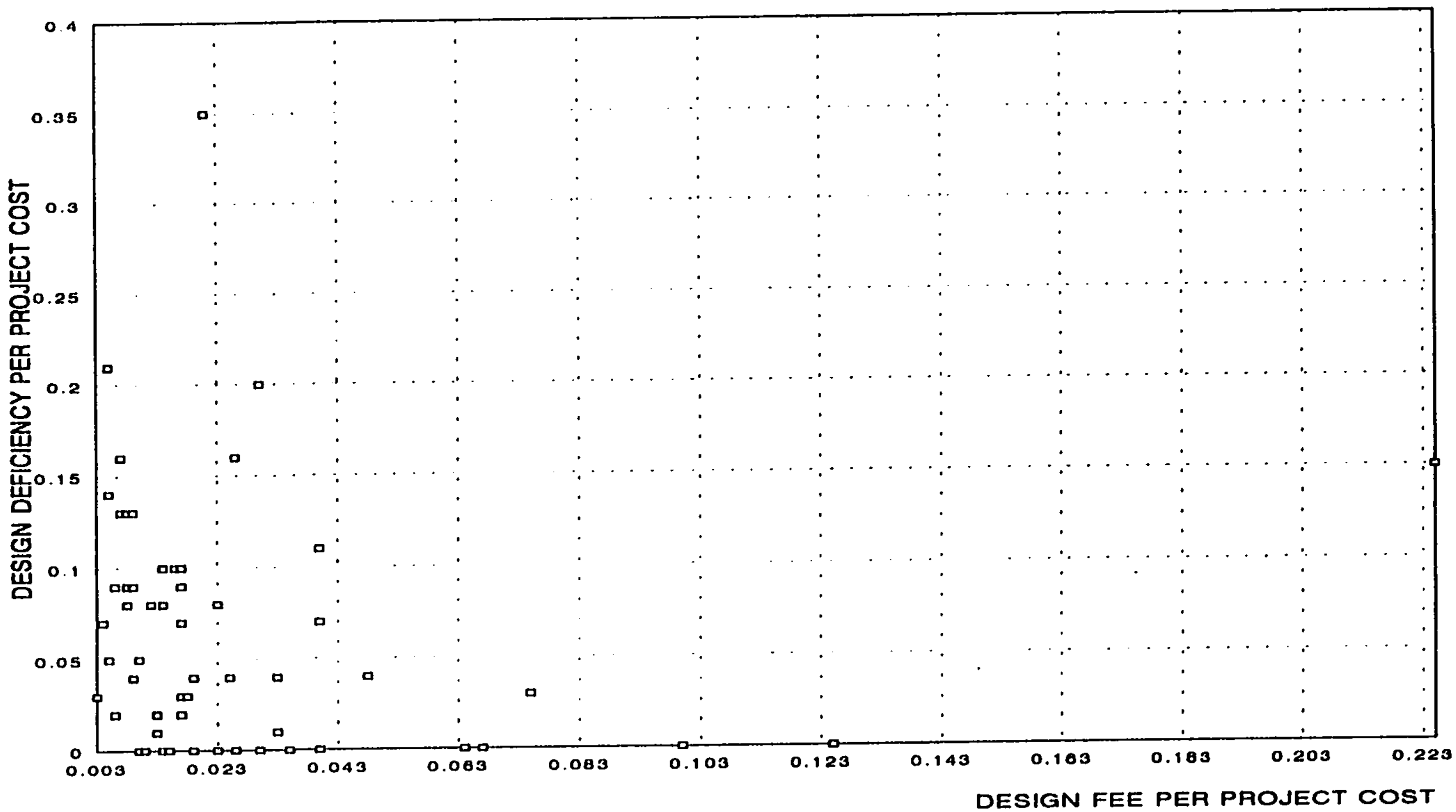


CHART 5.1 DESIGN FEE VERSUS DESIGN DEFICIENCY

The study of the nature of this projects reveals that it is a square beautification project. These type of projects always do not follow the normal design fee range because they include art work. The second project is three times the maximum design deficiencies cost and ten times the average design deficiencies cost. This also makes the project a special case that does not represent design deficiency range in local practice. Also the study of the this project reveals that the owner of the project is the contractor. These circumstances always attributes lots of design deficiencies.

The following are some of the statistics concluded from the project characteristics table.

A- Design fee statistics

Number of observations	58
Minimum value of design fee	0.3 % of the project cost
Maximum value of design fee	12.5 % of the project cost
Average value of design fee	2.4 % of the project cost
Median value of design fee	1.4 % of the project cost
Standard deviation	3.47 %

B- Design deficiency statistics

Number of observations	58
Minimum value	0
Maximum value	0.21 of the project cost
Average value	0.059 of the project cost
Median value	0.04%
Standard deviation	0.053

C-Project cost statistics

Number of observation	58
Minimum value	SR. 500,00
Maximum value	SR. 39,000,000
Average value	SR. 7,500,000
Median value	SR. 3,400,000
Standard deviation	SR. 8,900,000

Chart (5.2) shows the relationship between design fee per project and the real cost of design deficiencies per project cost after deleting the above mentioned two projects from chart (5.1). Studying the pattern of the plots, reveals the following points.

There is a general pattern that the cost of design deficiency tends to decrease as the design fee increases.

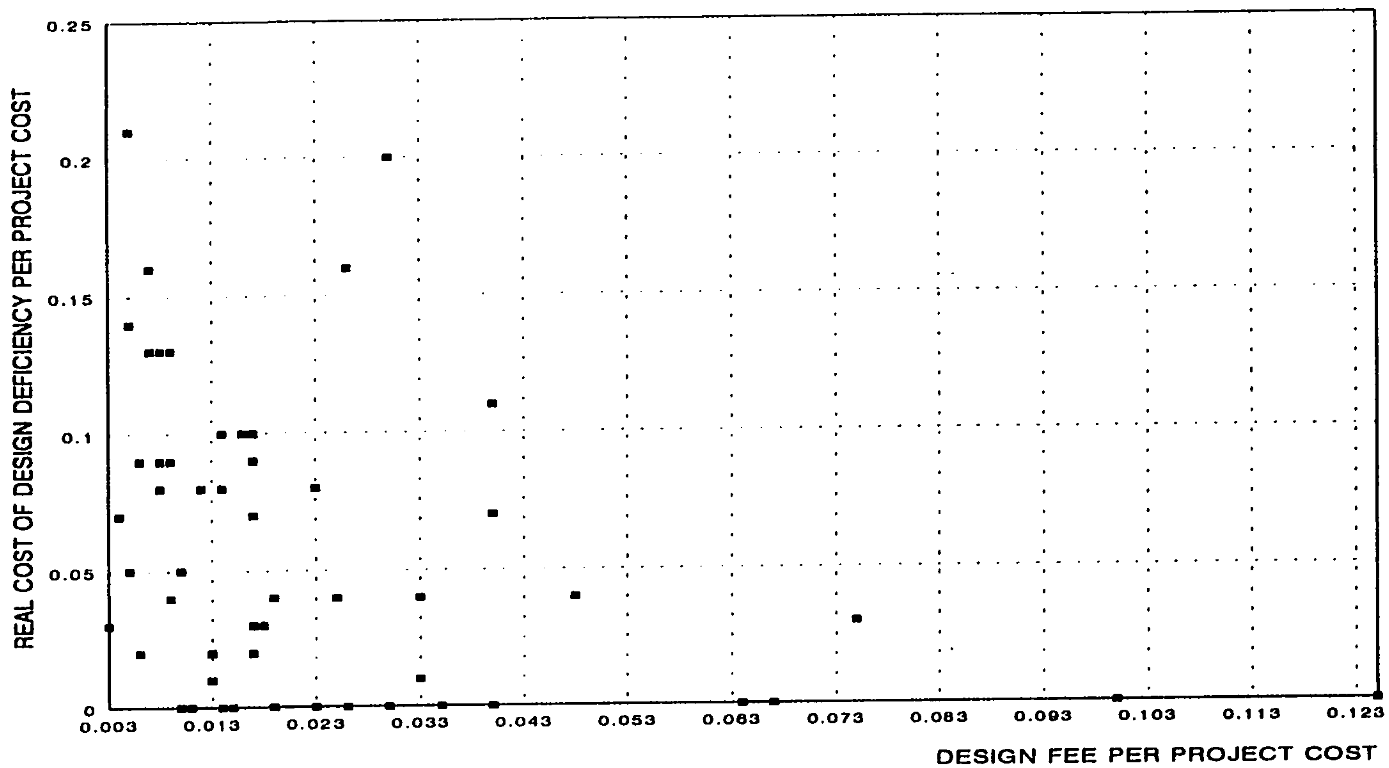


CHART 5.2 DESIGN FEE VERSUS DESIGN DEFICIENCY

The minimum design deficiency cost is 0.0 % and the maximum design deficiency cost is 21 %, of the project cost.

83 % of the projects are between design fees equal to 0.3 % and 3 % of the project cost; which refers to the low design fee range compared to international standards.

The cost of design deficiency variation of the offices with the same design fees is extremely high especially in the low design fee zone. This variation decreases substantially as design fee increases. For example, for design fee equals 0.4 % per project cost, design deficiency cost can be as low as 5 % of the project cost or as high as 21 % of the project cost. The range of the variation is 16 % of the project cost. However, for design fee equals 0.7 % of the project cost, the design deficiency can be as low as 2.5 % of the project cost or as high as 16 % of the project cost. The range of the variation of y values is 13.5 % of the project cost. In addition, when design fee is equal to 2.3 % of the project cost, the design deficiency can be as low as 0 % of the project cost or as high as 8 % of the project cost. The range of the variation of y values is equal to only 8 % of the project cost. Meaning that, the performance of the design office in term of their design deficiency cost tends to be more consistent as the design fee increases.

The estimated linear regression for chart (5.2) has R-square equal to 15.4 % which is not enough to explain the chart data. This result leads the researcher to try other nonlinear models.

Many trials were done in this regard before achieving the best estimated curve that represents the distribution of the chart points (Appendix 3 shows these trials) . This estimated curve is between the real cost of design deficiency on the Y-axis and the inverse of the design fee per project cost on the X-axis. The next model is the best regression model achieved to represent the data points:

$$y = a + a_1 (1/x) + a_2 (1/x)^3 + a_3 (1/x)^5$$

Where

$1/x$ is the inverse of design fee per project cost.

y is the correspondent design deficiency cost per project cost.

a is equal to -0.0029072715

a_1 is equal to 0.0986391512

a_2 is equal to -0.0155257005

a_3 is equal to 0.0007302215

The regression model has R-squared = 85 % which is considered acceptable for the analysis to depend on. In other words, the previously mentioned model explains 85 % of the variation in the data. Chart (5.3) plots the estimated curve resulting from the regression between the inverse of design fee per project cost on the X-axis and the real cost of design deficiency per project cost on the Y-axis for the 58 projects. The significance probability of this model is equal to 0.01%.

Chart (5.4) converts the inverse design fee of chart (5.3) into design fee. Thus the new chart represents the relationship between design fee on the X-axis and design deficiency on the Y-axis.

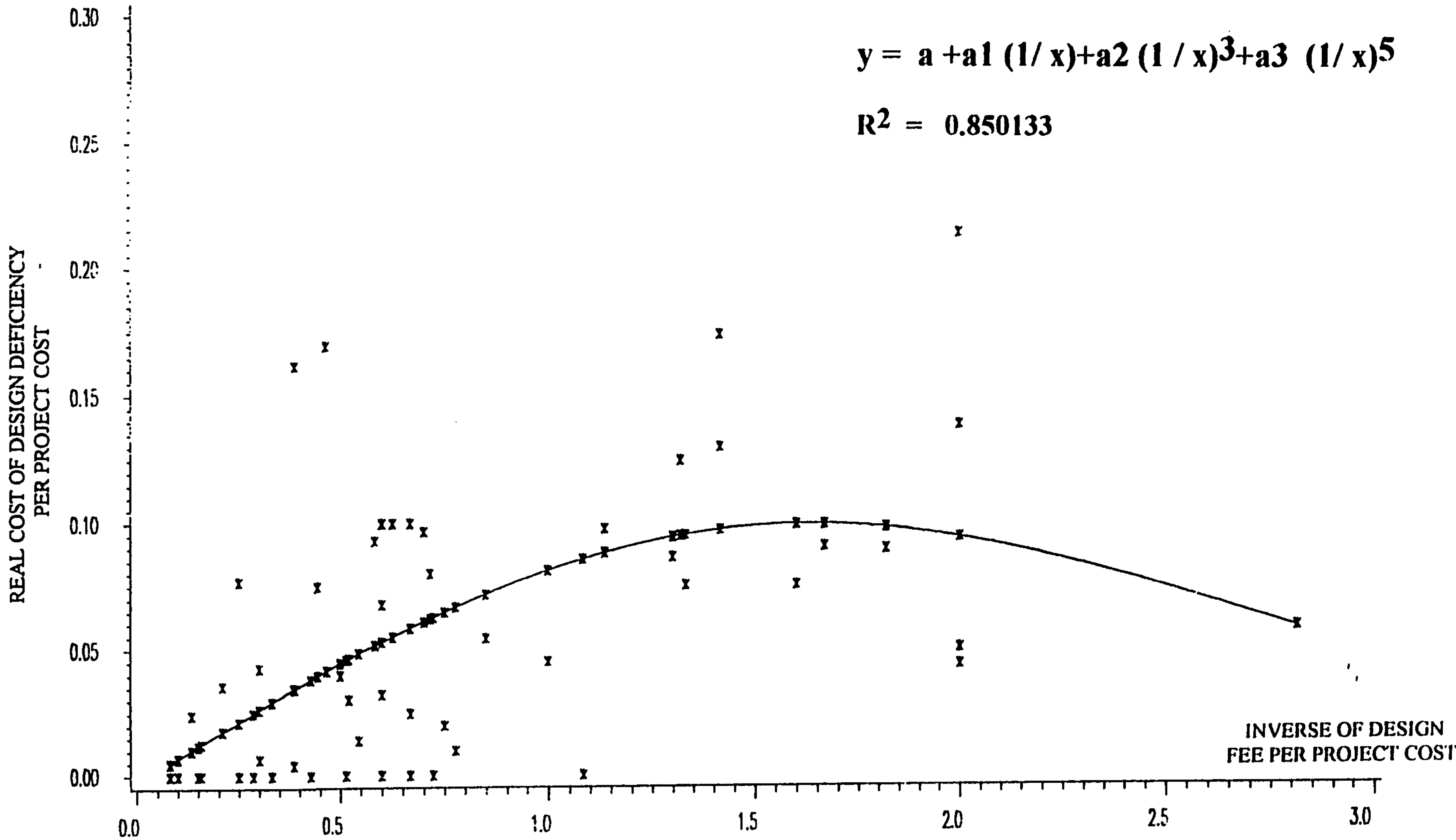


CHART 5.3. ESTIMATED CURVE BETWEEN INVERSE OF DESIGN FEE AND DESIGN DEFICIENCY

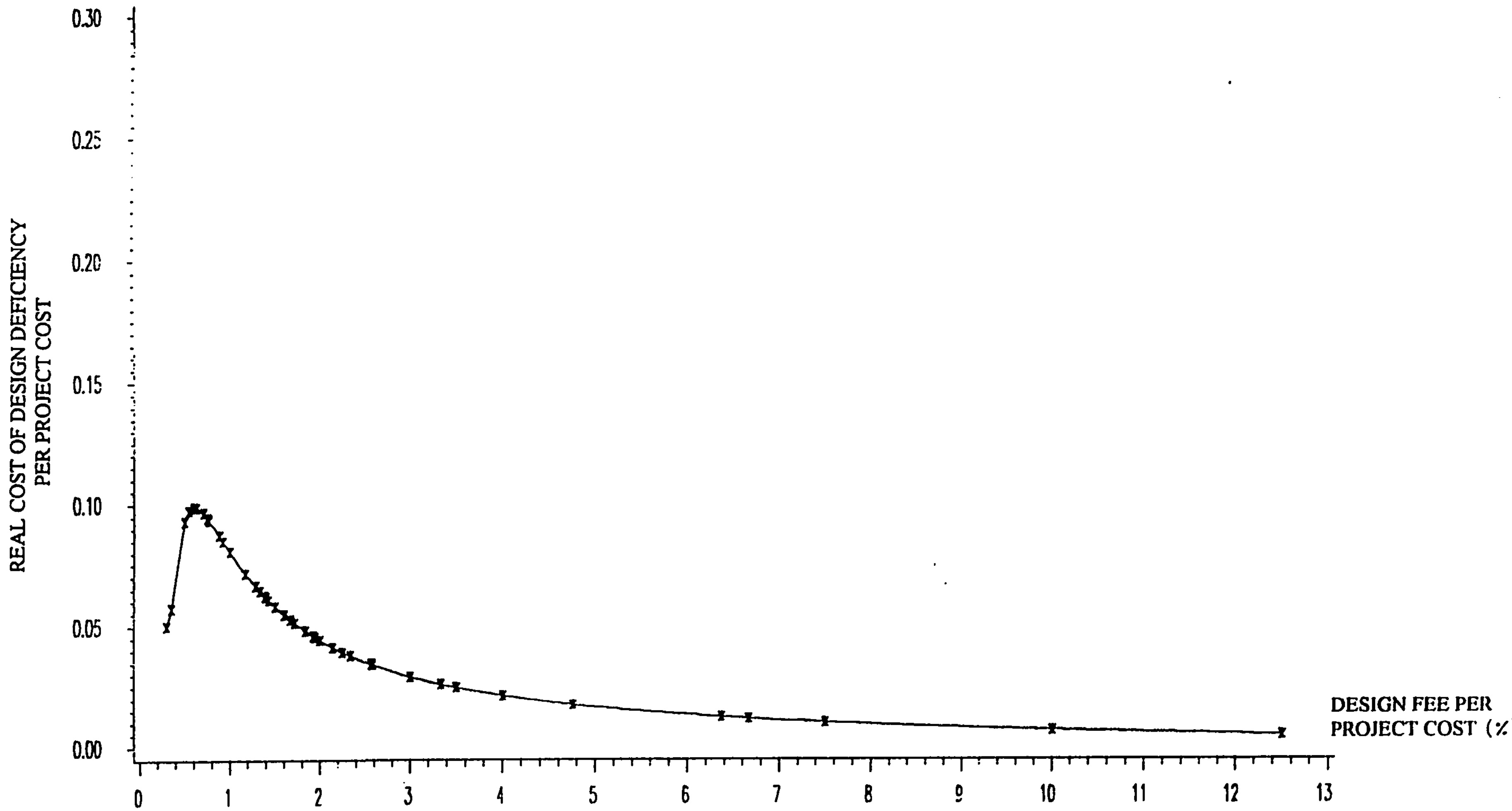


CHART 5.4. CONVERTED CURVE BETWEEN DESIGN FEE AND DESIGN DEFICIENCY

This conversion is done as follows:

1- Calculating the corespondent design fee values for the X-axis values.
2- Rearranging the x- axis scale in ascending manner according to the resulting design fee values.
3- Redrawing the curve according to the new X-axis scale.

The converted chart starts at point (design fee =0.3 % of the project cost and cost of design deficiency = 5 % of the project cost), then the cost of design deficiency increases as the design fee increases till it reaches the peak of the curve at point (x = 0.6 % of the project cost, y =10 % of the project cost) which represents the maximum value of design deficiency cost. Then the cost of the design deficiency starts to decrease as the design fee increases till it reaches the end of the curve at which the design fee is equal to 12.5 % of the project cost and the real cost of design deficiency is equal to 1 %. This represents the minimum cost of design deficiency.

Theoretically, the analysis of the curve in chart (5.4) is divided into three parts. The first part starts at point (x = 0.3 %, y = 5 %) and ends at point (x = 0.6 %, y = 10 %) with an average slope equal to 16.7. This slope reveals that the cost of design deficiency increases substantially with any increase in the design fee which is illogical. The second part starts at point (x = 0.6 %, y = 10 %) and ends at point (x = 3 %, y = 3 %) at which the slope of tangent to curve is equal to 1. The reason for choosing this point to end the second part is that the rate of increase in the design fees starts to be higher than the rate of decrease in the design deficiency cost. The second part represents a curve with an average slope equal to -2.9. This slope reveals a faster rate of decrease in the y value than the rate of increase in the x value. Meaning that, the costs of design deficiencies decrease substantially for every slight increase in the design fees. The third part starts at point (x = 4%, y =3 %) and ends at point (x = 12.5 %, y = 1 %) with an average slope of 0.33. This slope reveals that the rate of decrease in the y value is lower than the corespondent rate of increase in the x value. Based on the above analysis, the study can only depend on the second and the third part in explaining the relationship between design fee and design deficiency. The first part can be omitted form the analysis for the following reasons:

1- This part is based on five projects' data points. However the rest of the curve is statistically more sound since it is based on 53 projects' data points.
2- The range of this part (x = 0.3, x = 0.6) lies in the most fluctuating zone in terms of design deficiency cost as shown in chart (5.2). Therefore, this part of the curve is the most uncertain part in estimating the addressed relationship.
3- The study of the project characteristics Table 4.1 reveals that most of the projects in this part are villas which are constructed by small local contractors. The reliability of the construction records of these projects is highly questionable.

Based on the above, the research depends on chart (5.5) in explaining the relation between design fee per project cost and real cost of design deficiency per project cost.

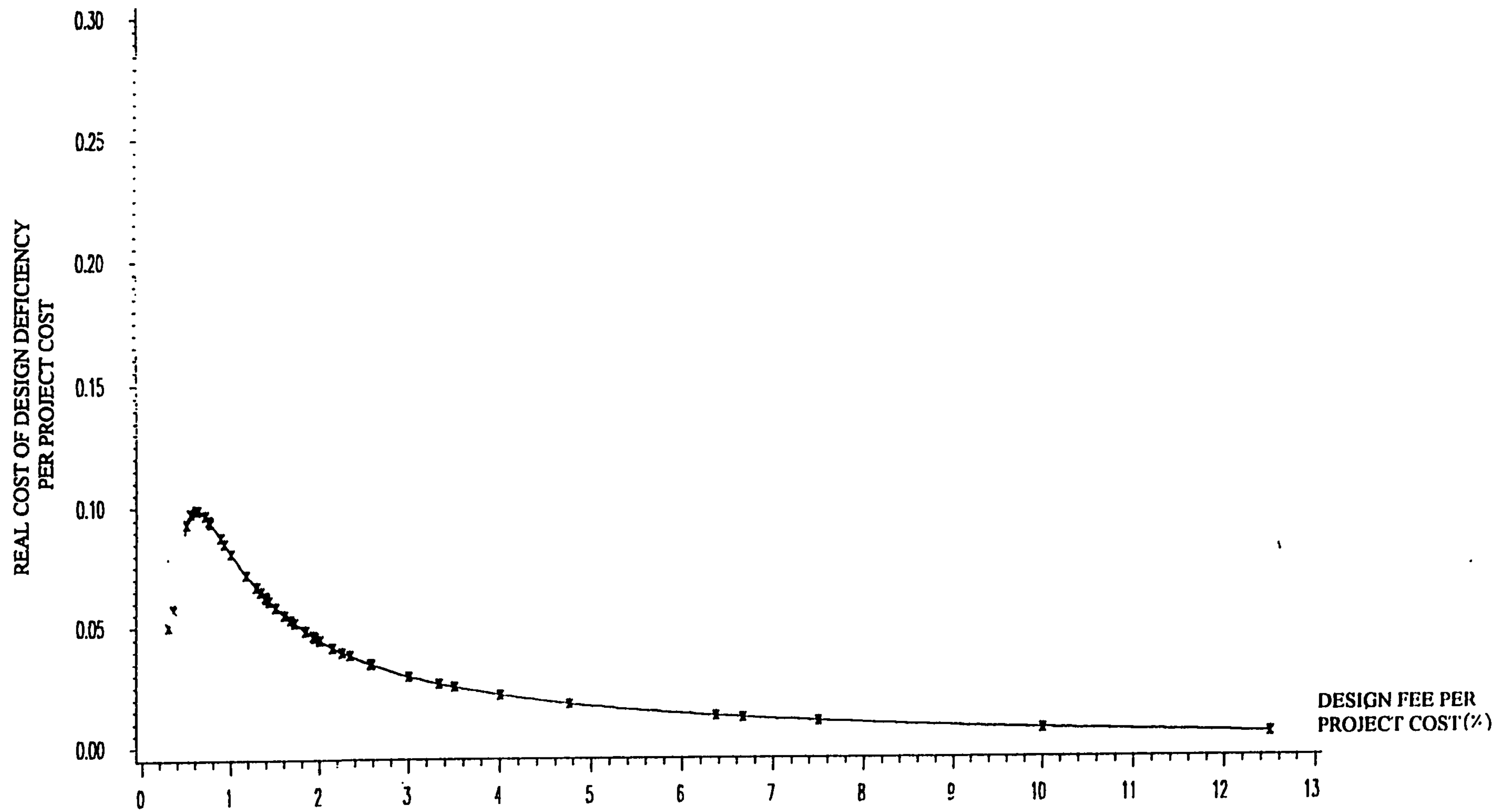


CHART 5.5. CONVERTED CURVE BETWEEN DESIGN FEE AND DESIGN DEFICIENCY

In conclusion, design fee has a non-linear inverse relation with design deficiency. By definition in this thesis, quality of design is equated to the design deficiency. The regression model shows a higher correlation between design deficiency (i.e. design quality) and design fee.

Design fee is a function of several components of the design office such as experience and credential of key personnel, time allotted for design and review and cost of associated systems. No doubt a good design which fulfill the requirements of the owner, contractor and regulatory agencies requires a lot of effort and resources which will add to the design fee.

The arguments made by the quality gurus regarding the association of cost and quality is worth mentioning. Crosby (198) stated that quality is free - lack of quality cost money. Deming (198) stated that quality is not free. Ishikawa (198) stated that quality control eventually leaf to substantial cost cuts. The three arguments can be safely extended to the relationship between design fee (which include the cost of quality conformance) and the cost of design deficiency. A question which is addressed by this study is the optimum design fee associated with the minimum cost of quality. the following paragraph discusses and recommend an optimum design fee for Dammam metropolitan area.

5.1.2 The Economics of Design Fee Versus Design Deficiency

Chart (5.6) represents the relationship between design fee and total quality costs. This quality costs is the sum of design fee and design deficiency costs. The study of the resulting curve reveals that 3% of the project cost is the most

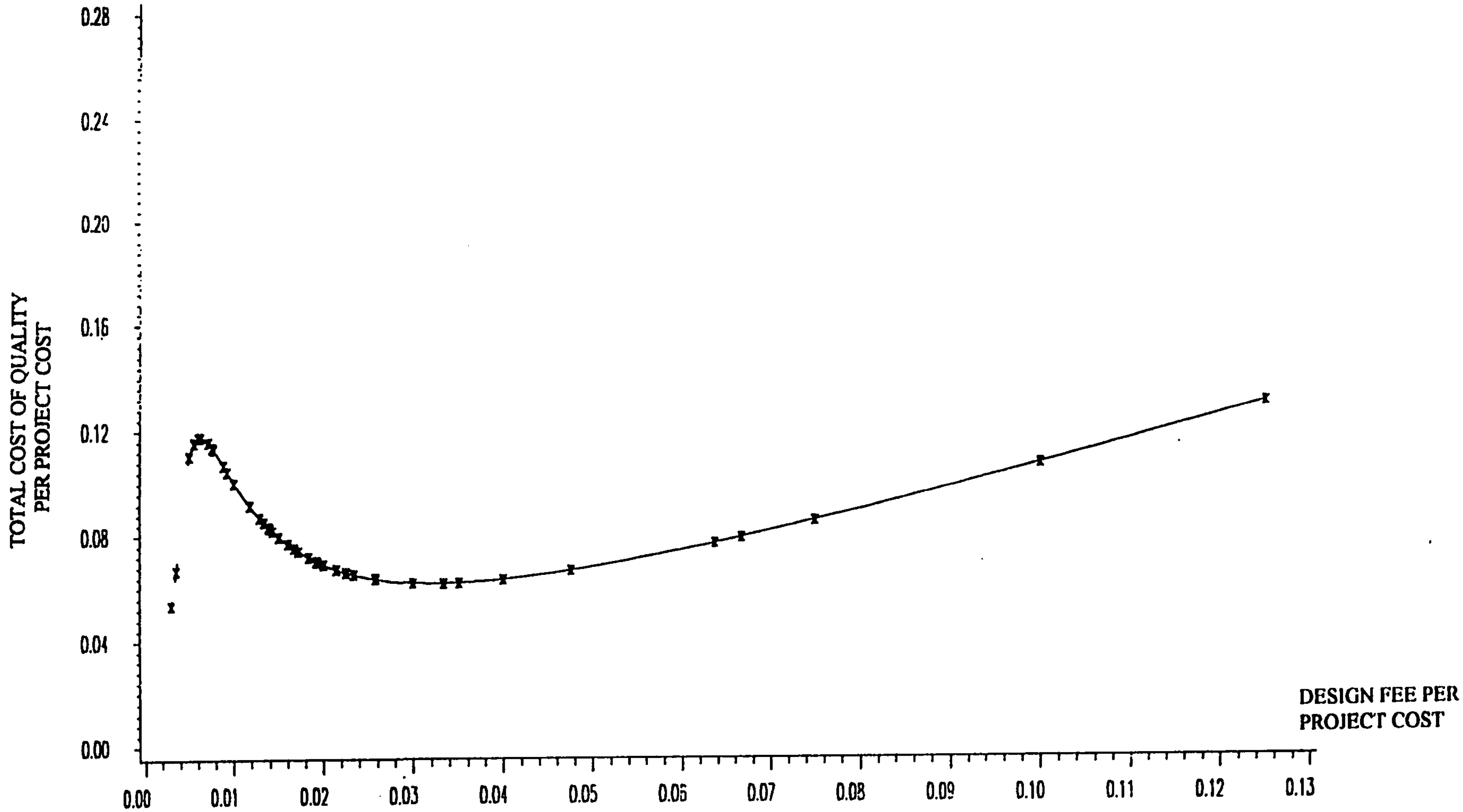


CHART 5.6. ECONOMIC CURVE BETWEEN DESIGN FEE AND TOTAL COST OF QUALITY
(DESIGN FEE + DESIGN DEFICIENCY)

economical design fee, because the tangent of the curve in at this point is equal to 0. Thus, paying more or less than 3% for design fee increases the total costs that the owner incurred. The reason for increasing the total costs when paying higher design fees is that the rate of decrease in the design deficiencies costs is less than the rate corresponding increase in the design fee costs.

The conclusion of the first path analysis yields the following results:

1- Design fee per project cost relates inversely to the real cost of design deficiency per project cost.

2- 3 % of the project cost is the most economical design fee in terms of total quality costs.

5.2 The relationship Between Design Deficiency and Office Components

In order to determine the office components that contribute to controlling design deficiency, this research chooses canonical correlation analysis. This kind of analysis can cross examine the relationship between two sets of variables, in this case between design deficiency and office components.

Canonical correlation analysis

This process depends on running an analysis between design deficiency with the office components data namely:

> Number of staff in each specialization, experience of the key personnel staff in each specialization, total number of employees in the office, office experience in the field, charging system, design fee foe a 500 m. sq. villa, services available in the office, review system, owner-architect contract agreement type and computer program used.

Based on canonical correlation analysis, table (5.1) represents the probability of rejecting the relationship between each office's components and design deficiency. For example, the significance probability of the number of architects is equal to 0.0958. This means that the probability of rejecting the number of architects as a factor affecting design deficiency is equal to 9.5%. That is to say this factor is an important one.

Table 5.1. The significance probability for the regression coefficients between office components and design deficiency

Office Components	significance Probability	Office components	significance Probability
No. of architects	0.0958	No. of structural engineers	0.1513
No. of electrical engineers	0.1294	No. of mechanical engineers	0.2009
No. of construction managers	0.0991	No. of draftsmen	0.4552
Chief architect experience	0.1389	Chief structural engineer experience	.0958
Chief electrical engineer experience	0.1012	Chief mechanical engineer experience	0.5782
Chief construction managers experience	0.1447	Chief draftsmen experience	0.7423
No. of employees	0.1228	Office experience	0.0804
No. of landscapers	0.2042	Chief landscape experience	0.1913
No. of interior designers	0.7166	Chief interior designer experience	0.3946
No. of value engineers	0.6587	Chief value engineer experience	0.8717

From the table, it can be seen that the significance probability varies enormously among the office components. Architects, electrical engineers and office experience are among the factors that have a strong relationship with design deficiency. By contrast, draftsmen, interior designers and value engineers are among the factors that have a weak relationship with design deficiency.

To understand the reason behind the varied effects of these factors on design deficiency, the following discussion is presented.

5.3 Discussion of the Controlling Factors of Design Deficiency.

The main aim of this division is to explain why design fee, number of architects, number of electrical engineers, number of construction managers, chief architect experience, chief electrical engineer experience, chief structural engineer experience, number of staff in the office and office experience in the field are the most important controlling factors that affect design deficiency cost.

5.3.1 Design Fee

There are several requirements or facilities needed in order to provide a quality services in the engineering firms. Some of these facilities or requirements are:

1. Assign adequate time to the design process.
2. Attracts qualified and creative staff.
3. Provide the needed engineering disciplines.
4. Acquire state-of-the-art of supportive equipment.
5. improve management systems.

There is an associated cost with the above requirements. The structure of the design office usually proportionally incorporate the cost of all facilities provided. Therefore, the higher the design fee is the higher the owner expectation regarding facilities and quality requirements.

5.4.2 Office Controlling Components

Design office structure components can be divided into two groups in terms of their influence on design deficiency cost. The first group includes architects, electrical engineers, office structural engineers and construction managers. This group is considered the most important component in affecting design deficiency cost. The second group includes interior designers, landscape architects, mechanical engineers, planners, draftsmen, value engineers and supervisors. This group has a weak effect on design deficiency costs.

5.4.2.1 Analysis of the First Group of Components

a- Architect

There are several reasons that make the architect a very important factor controlling design deficiency cost namely :

1. He is the contact person with the clients.
2. He is the coordinator of the design team and design process.

3. He is the responsible person for 70 % of design deficiency types namely, partitions, plumping, finishes, missing details and interdisciplinary coordination.
4. He is the person responsible for the success or the failure of the project.

Therefore, any improvement in the architecture department's performance in terms of number of staff and experience contribute to reducing design deficiency cost.

b- Electrical engineer

Electrical specialization is also considered an important specialization that affects design deficiency. This is because the high standard of living and hot climate in Saudi Arabia causes the electrical works to consume a major portion of the project cost. In addition, electrical works in many small scale projects are not given enough attention in the design stage. This left until the construction stage. This leads to high electrical deficiency costs. Therefore, any improvement in the electrical department in terms of number of staff and experience improve the design quality.

c- Office structure

Increasing office staff contribute to reducing design deficiency cost because of the following reasons:

1. It establishes sort of peer review inside the office.

2. It injects teamwork and cooperation inside the office which increases the degree of creativity in the office designs.
3. It widens the concept of experience exchange between office employees for better design quality.
4. It increases the chances of having a wider range of professions which improves the quality performance of the office.

On the other hand, increasing Office experience in the local consultant field improves office performance because of the following reasons:

1. It creates better understanding of the problems of local practice problem and corrective action to deal with them.
2. It allows better understanding of the clients' needs and the methods of achieving them.
3. It assists better communication with the client.
4. It establishes an effective management system that accomplishes all the practice requirements.
5. It avoids making the common design deficiencies.

Based on the previous information, office structure is considered one of the important factors that control design deficiency cost.

d- Construction manager

There are several reasons that make the construction manager an important factor in controlling design deficiency cost namely :

1. He provides the architect with the field information that establishes more practical solutions in terms of the construction process.
2. He provides the design team with the latest construction techniques and methods that improve the project quality.
3. He is the most qualified person to review contract documents before letting the project for construction.

Therefore, improving construction management contribute to reducing design deficiency cost.

On the other hand, although number of construction managers is a factor that contribute to reducing design quality, the correlation coefficient of the construction managers' experience is less than that of the architect and electrical engineer.

Chart (5.7) shows that the minimum experience for the construction managers is 10 years. This indicates that construction managers' experience is not a factor in determining design deficiency, since all the construction managers in the field have enough experience.

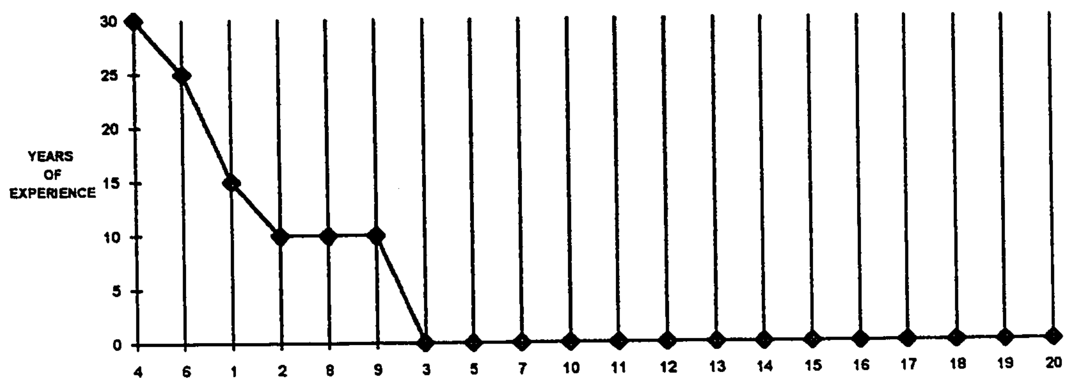


CHART 5.7. DESCENDING ORDER OF DESIGN OFFICES ACCORDING TO THIER CONSTRUCTION MANAGER EXPERIENCE

e- Structural engineer

Although it is believed among construction practitioners that both number of staff and experience of the structure department are important in determining project quality, the data shows that only the structure engineer's experience is the controlling factor in design deficiency cost. This is because most of surveyed projects are ordinary building projects with elementary structural problems which can be handled by one experienced structural engineer rather than many inexperienced structural engineers. For example, the main structural problem in the surveyed projects is the over design of the reinforcement steel. The causes of this problem are:

1. The fear of the junior structural engineer from the tropical climate's and the corrosion effect on the performance of the reinforced concrete.

2. The limited time available to the structural engineer in the low design fee offices to calculate and review a suitable quantity of the reinforcement steel. Therefore, the junior structural engineer tends to increase the reinforcement steel to guarantee the building safety.

In this regard, only the experience of the structural engineer is more crucial than the number of structural engineers in determining the structure design quality.

5.4.2.2 Analysis of the Second Group of Components

a- Interior designer and landscape architect:

The main reason for low correlation coefficient is that most of the surveyed projects are building projects. The involvement of the interior and landscapers designers in this kind of project is relatively small and mostly affects the aesthetics of the building. Therefore, the role of these specialists determine another aspect of project quality which is not measured by this research.

b- Planners:

Most of the surveyed projects do not require the planning expertise in their design process. Therefore, the correlation coefficient is very low.

c- Mechanical Engineer:

Unlike the industrial projects, the role of the mechanical engineer in building projects is relatively small. This role depends mainly on designing small air-conditioning systems and elevators. Besides, some of the air-conditioning systems are designed by the electrical engineers in the office. Therefore, the cost of mechanical changes is too small to be a controlling factor in the total design deficiency cost.

d- Draftsmen:

The role of draftsmen is only to execute shop drawings that are continuously supervised by the designer. The probability of error in this context is very low. Therefore, neither the number of draftsmen in the office nor their chief experience plays an important role in controlling design deficiency cost.

e- Value engineer:

The role of the value engineer is related more towards reducing project cost and increasing the value of the project in terms of functionality and specification. On this regard, the value engineer can not detect the design mistakes resulting from contract document conflict, interdisciplinary coordination errors and technical compliance discrepancies that are measured by the research as design deficiencies. Therefore, the correlation coefficient of the value engineer is low.

f- Supervisors:

The role of the supervisors comes after letting the project run to the construction stage. This role is limited to supervising the contractor's work according to the project drawings. This means that there is no contribution from the supervisors in the design stage. Therefore, the contribution of the supervisors in controlling design deficiency is extremely low.

CHAPTER SIX

MARKET PERFORMANCE

The first aim of this chapter is to evaluate the general performance of the consulting market in the Eastern Province in terms of design fee and each of the resulting office components that contribute to controlling design deficiency cost namely; design fee, number of architects, number of electrical engineers, number of construction managers, chief architect experience, chief electrical engineer experience, chief structural engineer experience, number of staff in the office and office experience. This evaluation present condition of such factors. The second aim is to discuss the field professionals opinions to obtain a comprehensive coverage of the other factors that are believed to affect design quality.

6.1 Evaluation of Market Performance

This section examines the frequency charts of the selected design offices for design fee and each of the resulting office components that contributes to controlling design deficiency. The examination is based on comparing the design offices distribution for each factor with the normal distribution chart. The comparison depends on determining the skewness coefficient value for every chart. The following clarifies the possible results for this comparison (chart 6.1):

Zero Skewness Coefficient value means that the design offices is normally distributed.

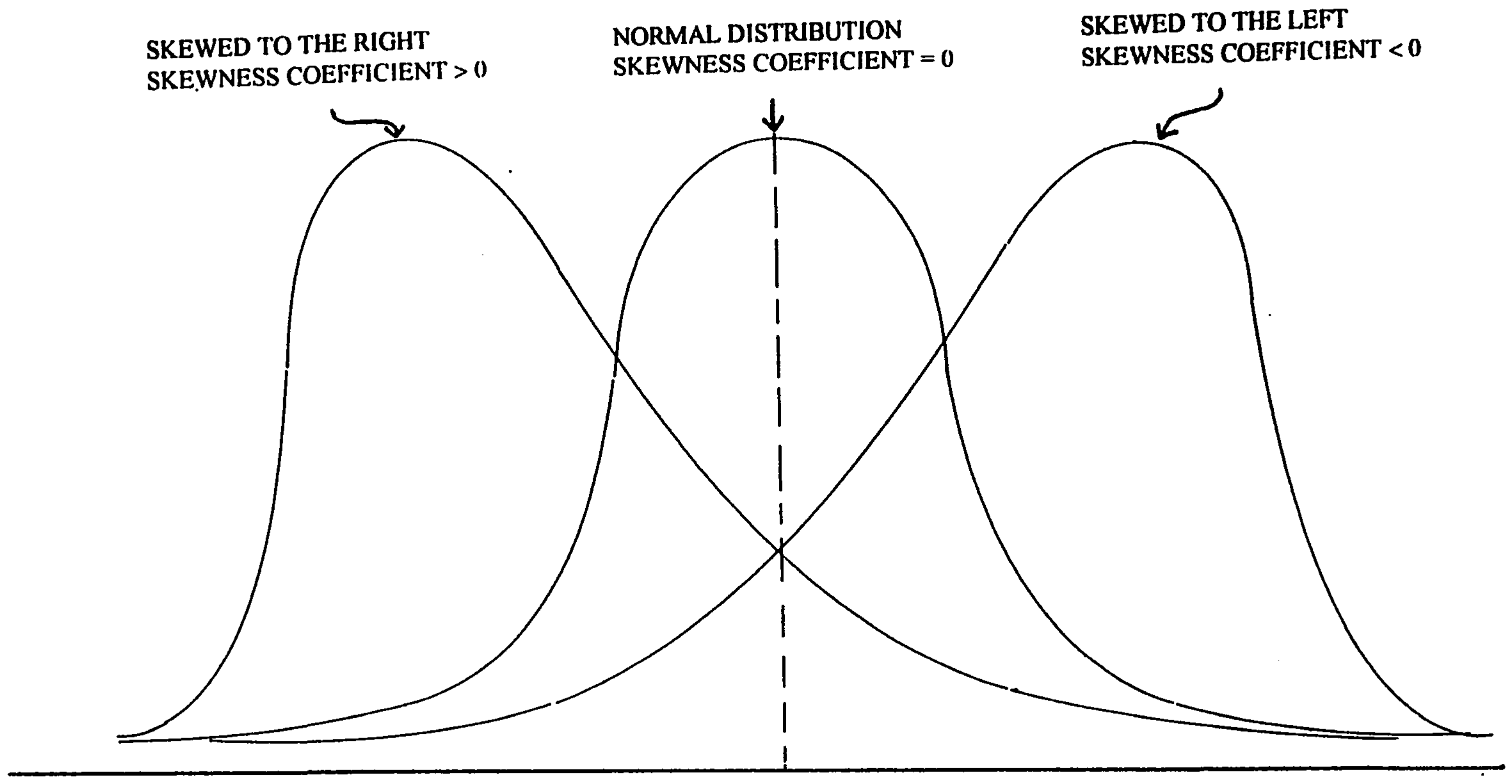


CHART 6.1. POSSIBLE DISTRIBUTION CURVES

High Positive skewness coefficient value means that the distribution of design offices is concentrated in the low zone on the scale of this factor.

High negative skewness coefficient value means that the distribution of design offices is concentrated in the high zone on the scale of this factor.

Small positive or negative skewness coefficient value, means that the design offices are mostly normally distributed in this factor.

6.1.1 Design Fee

Chart (6.2) shows the selected design offices in a descending order according to their average design fee per project cost.

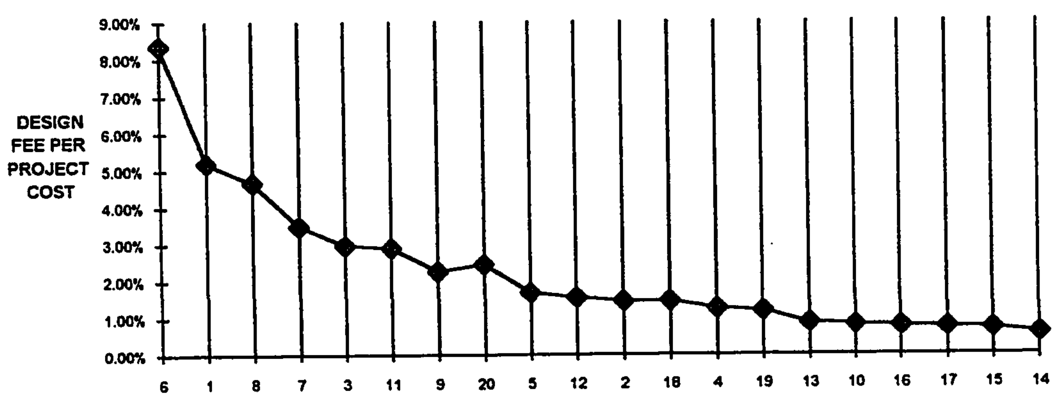


CHART 6.2. DESIGN OFFICES IN DESCENDING ORDER ACCORGING THEIR AVERAGE

Minimum design fee	0.6 % of the project cost
Maximum design fee	8.37 % of the project cost
Average	2.27 % of the project cost
Median	1.47 % of the project cost
Standard deviation	1.9 %
Skewness coefficient	0.42

Chart (6.3) shows the frequency of design offices on the different design fee ranges.

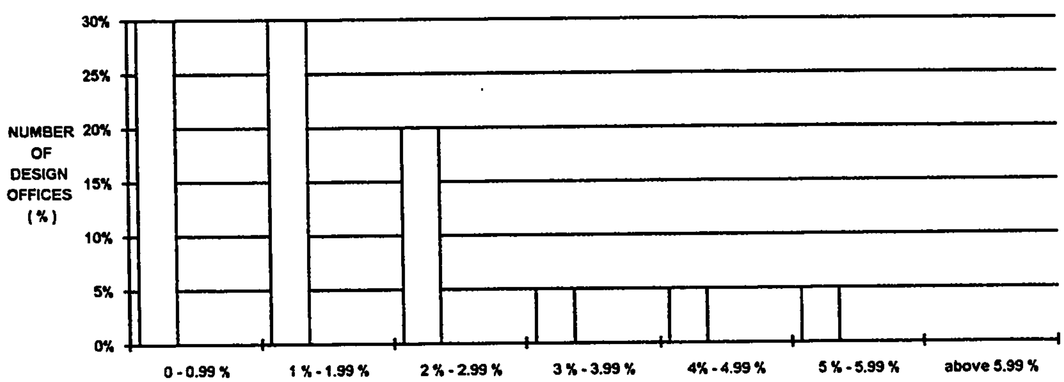


CHART6.3. NUMBER OF DESIGN OFFICES WITH DIFFERENT RANGES OF DESIGN FEE

The histogram shows that the distribution of the design fee in the market is very skewed to the right as realized from the high skewness coefficient. Meaning that, the average design fee in the market is more concentrated in the low design fee zone as evidenced by the mode which is equal to 1 % of the project cost. In addition, it is noticed that 80 % of the average design fee for the local design offices is below the economical design fee which results from the analysis. In conclusion, there is a good potential to increase design fee. This increase should be used for quality of performance and continuos improvement.

Number of Architects

Minimum number of architects	1 architect
Maximum number of architects	8 architects
Average	3.3 architects
Median	3 architects
Standard deviation	1.7
Skewness coefficient	0.165

Chart (6.4) shows the frequency of design offices with different number of architects.

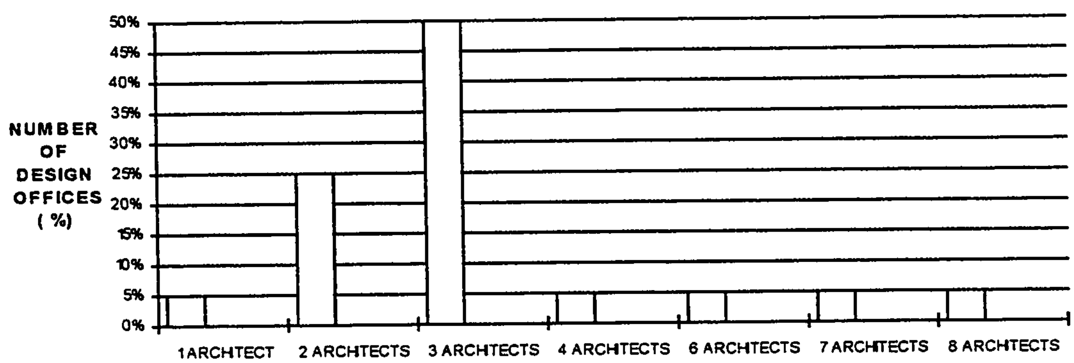


CHART 6.4. NUMBER OF OFFICES WITH DIFFERENT NUMBER OF ARCHITECTS

The distribution of the number of architects in the local design offices is also skewed to the right, but with less degree than that of the design fee histogram. Meaning that, the general number of architects in the market is more related to those offices which have few architects on the local scale.

6.1.3 Number of Electrical Engineers

Minimum number of electrical engineers	0
Maximum number of electrical engineers	10 electrical engineers
Average	3.3
Median	1 electrical engineers
Standard deviation	1.7
Skewness coefficient	0.53

Chart (6.5) shows the frequency of design offices with different number of architects.

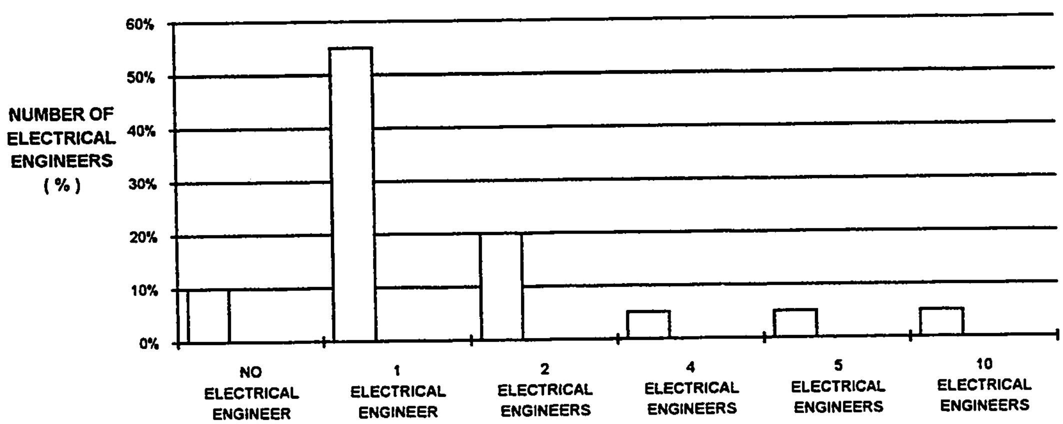


CHART 6.5. NUMBER OF DESIGN OFFICES WITH DIFFERENT NUMBER OF ELECTRICAL

The most common number of electrical engineers is one electrical engineer. In addition, the distribution of the number of electrical engineers in the design offices is very skewed to the right as revealed from the skewness coefficient. Meaning that, the average number of electrical engineers in the market is more related to those design offices which have very few electrical engineers on the local scale of number of electrical engineers.

6.1.4 Number of Construction Managers

Minimum number of construction managers	o
Maximum number of construction managers	19 construction managers
Average	2.05
Median	0
Standard deviation	1.7
Skewness coefficient	0.422

Chart (6.6) shows the frequency of design offices with different number of construction managers.

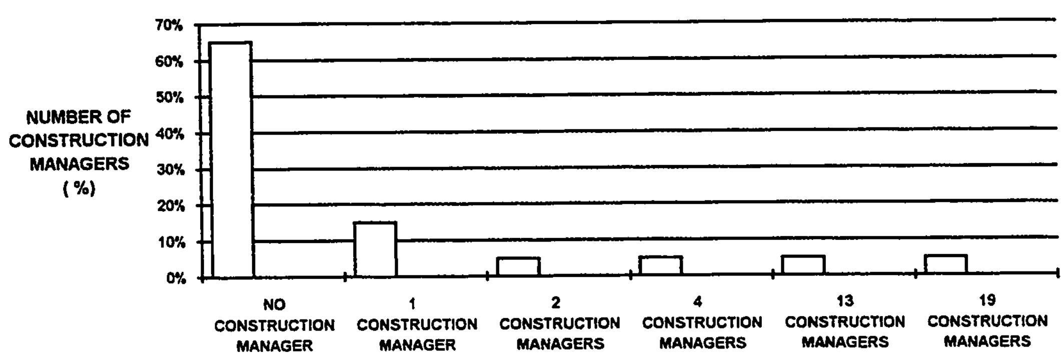


CHART 6.6. NUMBER OF DESIGN OFFICES WITH DIFFERENT NUMBER OF CONSTRUCTION MANAGERS

The most common number of construction managers is zero construction managers. In addition, the distribution of the number of construction managers in the design offices is also highly skewed to the right as evidenced by the skewness coefficient. Meaning that, the average number of construction managers in consulting offices is more related to those offices which have very few construction managers on the local scale.

6.1.5 Chief Architect Experience

Minimum years of experience	3 years
Maximum years of experience	35 years
Average years of experience	14.75
Median	14 years
Standard deviation	7.777
Skewness coefficient	0.009

Chart (6.7) shows frequency of design offices with different ranges of chief architect experience in the selected offices.

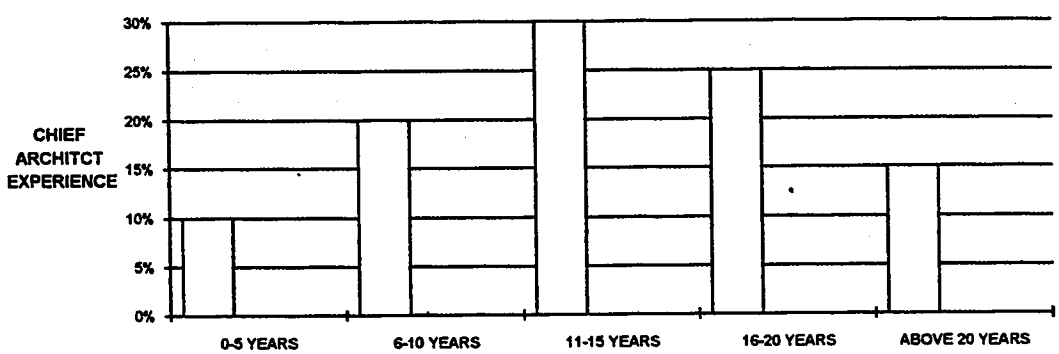


CHART 6.7
. NUMBER OF DESIGN OFFICES WITH DIFFERENT CHIEF ARCHITECT EXPERIENCE

The most common range of chief architect experience is 11-15 years. The distribution of the chief architect experience in the design offices is in general normally distributed with a slight skewness to the right. Meaning that, the general chief architect experience in the design offices is mostly equal to the average.

6.1.6 Chief Structure Engineer Experience

Minimum years of experience	5 years
Maximum years of experience	25
Average years of experience	13
Median	13 years
Standard deviation	5.58
Skewness coefficient	-0.23

Chart (6.8 shows frequency of design offices with different ranges of chief structural engineer experience in the selected offices.

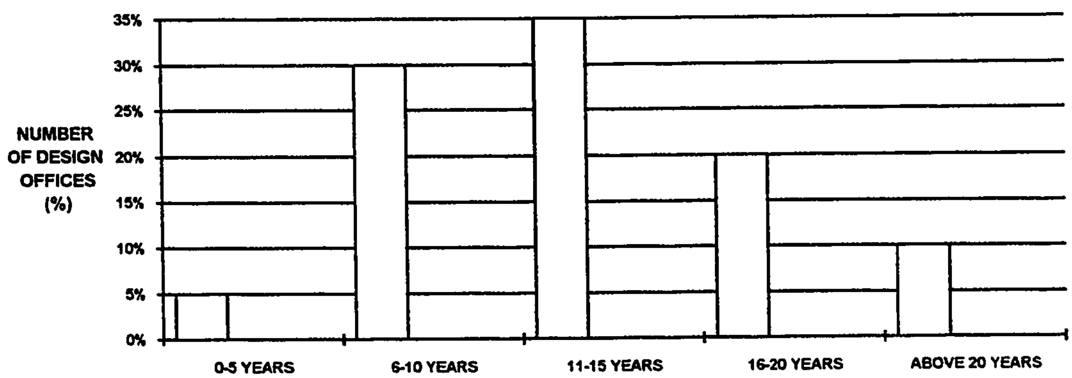


CHART 6.8. NUMBER OF DESIGN OFFICES WITH DIFFERENT CHIEF STRUCTURAL ENGINEER EXPERIENCE

The most common chief structural engineer experience is between 11-15 years. The distribution of chief structural engineers in design offices is in general normally distributed with some skewness to the left. Meaning that, the general structural engineer experience in the design offices is above the average on the local scale .

6.1.7 Chief Electrical Engineer Experience

Minimum years of experience	0
Maximum years of experience	30 years
Average years of experience	14.4 years
Median	16.5 years
Standard deviation	9.518
Skewness coefficient	-0.217

Chart (6.9) shows frequency of design offices with different ranges of chief electrical engineer experience in the selected offices.

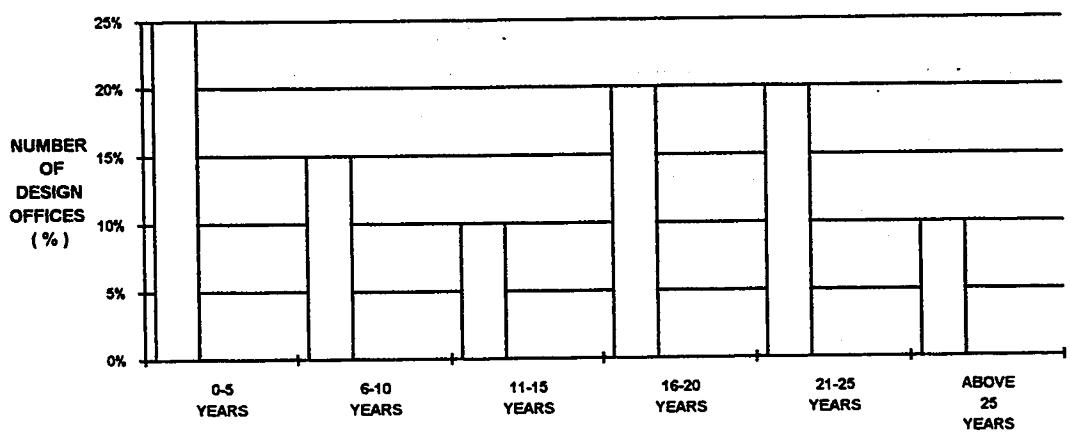


CHART 6.9. NUMBER OF DESIGN OFFICES WITH DIFFERENT ELECTRICAL ENGINEER EXPERIENCE

The distribution of the chief electrical engineer in the design offices is in skewed to the left as evidenced from the skewness coefficient. Meaning that, the general electrical engineer experience in the design offices is above the average on the local scale .

6.1.8 Office Experience in the Field

Minimum years of experience	3 years
Maximum years of experience	25
Average years of experience	12.45
Median	12.5 years
Standard deviation	5.82
Skewness coefficient	0.1

Chart (6.10) shows frequency of design offices with different ranges of office experience in the field.

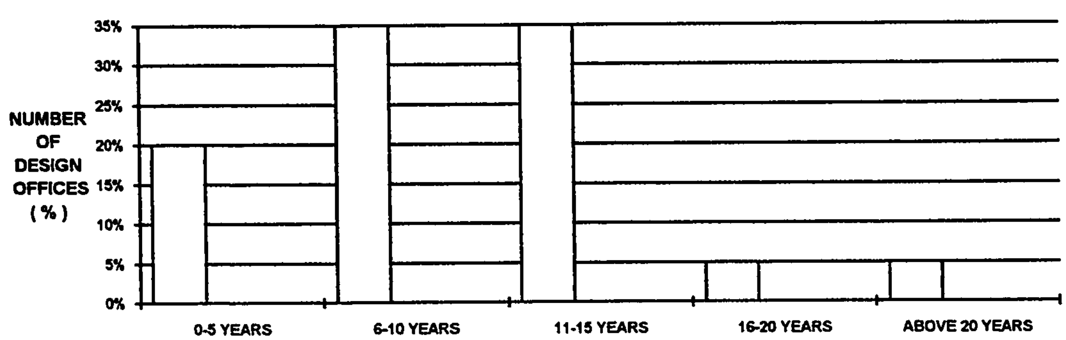


CHART 6.10. NUMBER OF DESIGN OFFICES WITH DIFFERENT YEARS OF EXPERIENCE

The distribution of the office experience in the market is skewed to the right as realized from the value of the skewness coefficient. Meaning that, the general design office experience in the market is mostly equal to the average on the local scale .

6.1.9 Number of Employees

Minimum number of employees	4
Maximum number of employees	141 employees
Average	26.75
Median	13 employees
Standard deviation	34.7
Skewness coefficient	0.396

Chart (6.11) shows frequency of design offices with different number of employees in the selected offices.

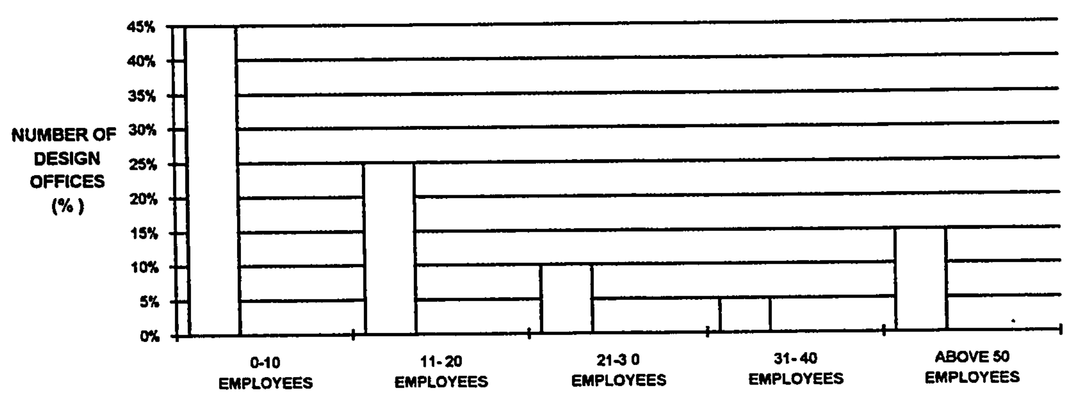


CHART 6.11. NUMBER OF DESIGN OFFICES WITH DIFFERENT NUMBER OF EMPLOYEES

The distribution of number of employees in the design offices is skewed to the right as realized from the positive skewness coefficient. Meaning that, the average number of employees in the market is more related to those design offices which have very few employees on the local scale of number of electrical engineers.

6.1.10 Summary and Discussion of the Market Evaluation

Table (6.1) arranges the skewness coefficient of the office components that contribute to controlling design deficiencies in a descending order.

Table 6.1. Skewness coefficients for design deficiency controlling factors

Factor Name	Skewness Coefficient
Number of electrical engineers	0.520
Number of construction managers	0.422
Design fee	0.420
Number of employees in the office	0.396
Number of architects	0.165
Office experience	0.100
Chief architect experience	0.090
Chief electrical engineer experience	- 0.217
Chief structural engineer experience	- 0.230

Based on the above table, the following points conclude the market performance of the controlling factors:

Although the design fee factor lies in third place in terms of the skewness coefficient, the research puts design fee as the most problematic factor that needs to be improved. This is because, design fee affects the office structure. Meaning that, the office components are dependent factors on design fee.

The number of electrical engineers, construction managers and office employees are the office components that have high positive skewness coefficient. Therefore these factors have the first priority to investigating the possible improvement .

The market performance of the design offices' architects in terms of number and experience is slightly below the normal distribution which means that architecture specialization in the design offices have less priority to investigating the possible improvement .

The experience of electrical and structural engineers in design offices proves to have the best distribution among the other controlling factors.

In conclusion, it is realized that the number of staff is more significant in the design offices rather than the experience.

6.2 Professional Opinions

In order to analyze the problem of design deficiency in local practice, the study depended on factual information derived from the interview questions. However, to obtain a comprehensive coverage of the problem, it is necessary to discuss the opinion of the professionals in the field to determine the other dimension of the design quality problem. The following are selected statements that reflect issues raised by the professionals during the interviews.

Contractors are the responsible party for quantity surveying of most of the private projects in the local practice . This is because, most of design offices do not present quantity surveying for their projects due to the low design fees they charge. This leads to the following drawbacks:

The owner does not have a reference to compare the project cost submitted by the contractors especially in lump-sum contract.

Calculating project quantities by the designer or his associates gives him a golden chance to pinpoint his design deficiencies before they become facts of life in other words it guarantees a second review for his project.

Selecting design office in the local practice is based on its design fee and verbal repetition among close friends .This always leads to not getting the most qualified design office for the job.

As mentioned earlier in the thesis, the best method for selecting design offices is based on design offices professional qualifications. Therefore, unsuitable selection of the design office jeopardizes project quality from the beginning.

Limiting projects approval from the municipality side to mainly elevations approval leads to the following points:

It directs most of the offices efforts toward solving beautiful elevations regardless of the project function and technical quality.
Despite these efforts the elevations do not necessarily represent a quality design rather the architectural beliefs of the reviewer. In this regard, knowing what style of elevations satisfies the reviewer becomes a crucial point in having the project approved.

As long as there are no standards for evaluating the elevations and there are a lot of reviewers with different educational backgrounds and architectural beliefs in each municipality, the criteria for approving the project varies from one reviewer to another in a giving municipality.

With time, design offices and owners understand the system in the municipality. Therefore, they build a data base file for each reviewer and they design the elevations to meet the style of one of the reviewers to guarantee approval. This system is considered the most dangerous weapon as it kills creativity.

Eventually, design offices are evaluated by people for their speed in having the elevations approved not on their design quality.

The absence of a role that sets minimum pre-qualification conditions to open a design office.

This situation encourages a lot of unqualified personnel to enter the business by opening small offices that consist of one architect, one draftsman and a copy machine doing all the work of a whole engineering team. These design offices are the main cause of the huge number of design deficiencies in the constructed projects.

The lack of a *predetermined project budget and The huge and consequent influence from the client's friends during the preliminary design stage is one of the main causes that increase the number of design changes.*

In this regard, clients tend to listen to their fiends' suggestion rather than the architect's. These suggestions always lack the enough experience and lead to improper solutions.

The owners tend to have more changes in their requirements when they do not have preset planning for their projects, consequently the design offices tend to pay less attention to the quality when there are a lot of changes in the project requirements.

The design offices do not spend enough time and effort in their design in order to make profit.

Many design offices work according to the fee paid to them regardless of the level of quality they produce in order to earn the same profit they always get. In other words in lump-sum contracts they preset the maximum time for the project in the office at the expense of quality. These offices usually under-estimate the design fee for the projects in order to secure the job, afterwards they prefer to reduce the design time not the office profit. In these cases the only victim is the project quality.

Most of the offices pay small salaries for their engineers in order to maximize profit on one hand, and compete with the low design fees in the market on the other hand.

Low salaries only attract unqualified or inexperienced engineers.

Senior engineers who have worked in the area for many years and had the most valuable experience usually leave the office due to the low salaries.

The rest of those who choose to stay usually reduce their effort, creativity and care to be equivalent to their salaries. At the very end the engineering profession is the only looser.

One of the crucial points in the client- architect communication problem is that the client looks to the architect as a draftsman for his needs not as a professional who can shape his needs in a high quality projects.

This attitude of the clients widens the communication gap with the architect. In this regard, clients only explain to the architect their requirements in terms of space size and allocation which always defer from their real needs. Later on, they find out that the projects does not fulfill their needs.

Low design fee is one of the causes of over designing the reinforcement. This can be explained as follows:

Low design fee shortens the required time for the design process in order to maintain profit. As a result the structural engineer will not find enough time to design and review the project structure accurately. Increasing the reinforcement far beyond the factor of safety appears to be the best solution.

Another reason is that many of the structural engineers came from different countries with deferent design codes and climates. They take into account the arid environment and the high corrosion level in Saudi Arabia and increase the reinforcement steel excessively over-assessing of these factors.

A third reason is that the junior structural engineer tends to use more reinforcement steel due to his lack of experience.

The strong competition between small offices makes some of them come up with a new idea to attract all the levels of clients. This idea is based on classifying the design services into several levels as follows :

Level A consists of fully detailed design with all working details, interior finishes and details, landscape details and quantity take off. It also specifies minimum number of sheets of not less than 50 sheets.

Level B consists of semi-detailed design with some working details and finish details. It also promises a number of sheets from 35 to 50.

Level C consists of regular design drawing with only the necessary drawings to build the structure and the architectural partitions without any kind of detailing or quantity take off.

Then, the office defers design fee range for every level. This arrangement guarantees that the office can compete with small offices that can only do the level C projects because they have only one architect, draftsman. This arrangement from the medium class offices is considered devastating to design quality due to the following reasons :

1- There is no classification of the issue of design quality by definition, either we have a quality design or not. In this case the level B and C are not related to the engineering profession at all.

2- Classifying design services by the qualified offices helps the non qualified and trading offices to flourish and continue corrupting the engineering profession.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Summary of the Results

The results achieved in the research, depend on two groups of data. The first group was collected by personal interviews with twenty design offices in the Dammam metropolitan area. The second group of data was collected by personal interviews with the contractors of three projects selected from each design office. The research results can be summarized as follows :

7.1.1 Design Fee Versus Design Deficiency Relation

Design fee has a non-linear inverse relation with design deficiency. In this relation, design deficiency per project cost decreases as design fee increases. The reduction rate in design deficiency cost decreases as design fee increases till reaching a point at which the design fee per project cost is most economical. The design fee at this point is in the range of 3 % of the project cost.

7.1.2 Office Components which Contribute the most to Controlling Design Deficiency

The research reveals that the architects and electrical engineers are the most significant specializations in the design office that contribute to controlling design deficiency. Therefore, any improvement to these specializations in terms of number of staff and experience shall contribute to reducing design deficiency costs. In addition, the following factors were found to also affecting design deficiency:

1- Number of construction managers.
2- Number of employees in the office
3- Years of experience of the chief structural engineer.
4- Years of experience of the office in the field.

On the other hand, the data shows that the number of staff in the respective specializations is more significant than experience.

7.2 Conclusion

7.2.1 Research implications

The research implications can be divided into two important parts. The first part is a documentation of some important issues in local consulting practice in the Eastern Province. This documentation include profiles of change order, design deficiency, owner change order and design fee. The second part is highlighting other areas in the field for further researches. In this regard, the results achieved by this research can be a base point for further researches in the same area; studying the relationship between design deficiency and design fee in the context of all of Saudi Arabia. The main aim of these studies should be to develop local minimum design fee chart that expresses to local construction industry conditions and is compatible to the international standards. Another area is to study the issue of communication between the designer and the client and its implication on design quality. A third area is to study the problem of over-designing the reinforcement steel in the building projects as this proves to be a major problem evidenced by professional opinions.

7.2.2 Industrial implications

Determining the inverse relationship between design fee and design deficiency helps both clients and design offices to realize the importance of increasing design fees in order to reduce overall costs and maintain better quality. In additions, determining architects and electrical engineers as the most important specialization in the office structure affecting design deficiency, helps design offices to concentrate their efforts on developing these particular specialization in order to improve their design quality. In addition, the determination of these specializations establishes another measure for clients in order to compare between design offices. In this regard, the clients can compare between design offices depending on the quality of their architects and electrical engineers

7.2.3 Policy implications

The most important implication of the research results is that they draw the attention of the authorities responsible for the engineering profession to the need to revise the existing policies that organize the profession in order to raise the level of regulation in the profession for improving design quality. In this regard, the engineering authorities should raise the standards of approving project documents in the municipalities. This high standard would automatically increase the design fees in the design offices due to increasing design efforts. The increase in project quality would increase design fees as evidenced from the results of this research. Consideration should also be given to setting minimum standards for opening design offices.

7.3 Recommendations

Based on the research results, decreasing design deficiency requires investments on design components which will increase design fee. Practically, setting a minimum design fee regulation would not guarantee that design offices and clients would conform to this regulation, since it is difficult to control the amount of fee that the design offices charges.

In the light of the above and professional opinions, the research suggests the following recommendations to improve design quality in the local consulting industry:

1- An authority or third party such as municipality should set minimum standards for a project to be approved. These standards should require the following documents as a prerequisite:

   * A complete set of working drawings that includes architectural, structural, electrical and mechanical details.
   * Specification manual
   * Bill of quantity.

2- The authority should unify the format of the previous requirements. This recommendation is to ease the process of studying, revising and discovering design mistakes for municipality reviewers

3- The authority should extend its revision of the contract documents to cover the technical aspects of the projects. This means that the municipality should revise the structural, mechanical, electrical, plumbing and constructability of the project as well as the elevation style. This recommendation is advised to impose a higher degree of peer review from a third party in order to minimize the possibility of having design mistakes in the construction stage.

4- The authority should set minimum criteria in order to open design offices. These criteria should specify the minimum number of staff, minimum expertise, minimum specialization required and minimum equipment and tools.

Obviously, municipality role is a vital factor in the successful implementation of these recommendations. The extension of the municipality role needs lots of expenses to have the required manpower and specialization in order to review the projects. The research suggests that the municipality charges some fee as expenses for reviewing each project. The fee could be drawn from the saved money resulting from decreasing design deficiency.

7.3.1 Benefits expected from the new system

A. Raising projects approval standards would automatically forces the low design fee offices to increase their fees to compensate for their additional efforts.

B. The new regulation changes the attitude of competition in consulting offices from lowering their fees to increasing their design quality. This new attitude forces the small offices, that consist of only one architect and one structural engineer to either leave the market or bring the office up to standard by completing the design team with all specializations and the latest equipment in the field. In addition, these offices would try to hire the best staff in the business in order to produce higher design quality and increase their market share.

C. This competition among design offices to hire the most creative staff in the business will increase the salaries for excellent staff. This excellence awareness would develop the spirit of creativity among engineers which would make them compete in developing their capabilities, knowledge and awareness of the latest technology in the field.

D. It is not only expected to have large savings in the change order costs but also in all construction aspects; which is not within the scope of the study, for example, money and time spent in solving construction disputes between owner-architect, owner-contractor and architect-contractor. The reason behind this high expectation is the quality increase in the whole construction process. In addition, preventing disputes between construction parties creates a cooperative environment that helps all the parties to work together to develop the construction industry.

E. Increasing the expenditure on the design stage and allocating some funds for making peer review by a third party offers the following benefits:

1- Enables design offices to spend much more time on designing, studying, creating and reviewing the projects and still maintain higher profits than before.

2- Increases the time spent in communication between the design offices and owners. The ultimate goal of this communication is that design offices can understand exactly the owner's needs

3- Improves the design services that clients get from the design offices. In other words, it increases the value of money spent in the construction profession.

4- Rebuilds the trust in the design offices due to the decrease of design deficiency. As a result, the owner decreases his changes in the design stage and construction stage. This reduction in owner changes saves a lot of time and money spent in rework and corrections.

F. The fees paid to the municipalities as a reviewing expense enable them to play more important role in improving the construction industry. The following are some characteristics of this new role :

1- Establish a sufficiently qualified and large enough peer review team to review the projects before the approval for construction.

2- Organize seminars and training courses on all aspects of the construction industry.

3- Build monitoring programs that measure the different aspects in the construction industry in order to construct a data base information center.

4- Fund research and experiments in the universities to improve the industry.

5- Issue newsletters and periodicals that report the latest local construction news for the construction parties.

6- Organize quality assurance and quality control programs for the design professional.

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APPENDIX 1

DESIGN OFFICE INTERVIEW QUESTIONS

PART I

About the Design Office

1- Name and telephone number of the office?

....

2- What are the specializations in the office?

a- Architecture	....	b- Landscape	....
c- Interior design	....	d- Structure	....
e- Mechanical	....	f- Electrical	....
g- Planning	....	h-Construction Management.	....
i- Drafting	....	j-Value Engineering	....
k-Others (specify)	....		

3- How many employees ?

a- (0-5)	....	b- (6-15)	....
c- (16-30)	....	d- (31-50)	....
e- Above 50	....		

4- How many years of experience in the field?

a- (0-5)	....	b- (6-10)	....
c- (11-15)	....	d- (16-20)	....
e- Above 20	....		

5- How many years of experience do key persons have ?

a- Architecture	....	b- Landscape	....
c- Interior design	....	d- Structure	....
e- Mechanical	....	f- Electrical	....
g- Planning	....	h-Construction Management.	....
i- Drafting	....	j-Value Engineering	....
k-Others (specify)	....		

6- What is the system of reimbursement for design services ? specify?

a- cost plus (fixed fee, percentage) ....

b- man- hour ....

c- percentage of the project cost ....

d-lump sum ....

7- If lump sum, what is the average fee for a 500 meter square villa?

a- up to SR. 5000 .... b- 5000-15000 ....

c- 15000- 30000 .... d- 30000-45000 ....

e- above 45000 ....

8- Percentage of work type performed by the office ?

a- feasibility studies .... b- basic design service ....

c- specification .... d- value engineering ....

e- bid contract .... f- quantity take- off ....

g-supervision .... h- construction management ....

i- site selection .... j- environmental studies ....

k- project budgeting .... l- marketing studies ....

m- programming .... n- others ....

9- Do you keep records for design changes due to design errors for evaluation and follow up ?

No ....

Yes, please clarify ....
....
....
....

PART II

About the selected projects

No.	QUESTIONS DATA	PROJECT 1	PROJECT 2	PROJECT 3
1	Type of each project			
2	Location ?			
3	Date of design ?			
4	Date of construction ?			
5	Project area ?			
6	The contractor of each project ?			
7	Contractor grade?			
8	Number of hours spent in each project ?			
9	Reviewers for each project			

No.	QUESTIONS DATA	PROJECT 1	PROJECT 2	PROJECT 3
10	The process used in reviewing the project ?			
11	The construction cost of each project			
12	How much time delay due to contractor deficiencies			
13	Type of contract used with the owner			
14	Kind of agreement used ? verbal, brief, or detailed			
15	Services furnished in each project			
15	The data usually included in the project file ?			
16	Computer programs used in drawing the project ?			

PART III

1- How do you define project quality ?

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2- What are the symptoms of design deficiencies ?

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3- What are the sources for design deficiencies ?

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4- How can we eliminate DD. ?

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APPENDIX 2

CONTRACTOR INTERVIEW QUESTIONS

CONTRACTOR NAME :	TELEPHONE :
GRADE :	EXPERIENCE :

	PROJECT 1	PROJECT 2
DESIGN OFFICE		
PROJECT NAME		
PROJECT COST		
NUMBER OF CHANGE ORDERS		
COST OF CHANGE ORDERS		
TIME DELAY OF CHANGE ORDERS		
NUMBER OF DESIGN DEFICIENCY		
COST OF DESIGN DEFICIENCY		
TIME DELAY DUE TO DESIGN DEFICIENCY		
NUMBER OF OWNER CHANGE ORDERS		
COST OF OWNER CHANGE ORDERS		
TIME DELAY OF OWNER CHANGE ORDERS		
TYPE OF DESIGN DEFICIENCY & RESPONSIBILITY		

APPENDIX 3

DIFFERENT MODELS TRIALS OF THE RELATION BETWEEN DESIGN FEE AND DESIGN DEFICIENCY

General Linear Models Procedure

Number of observations in data set = 58

1

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.06209963	0.06209963	4.74	0.0341
Error	52	0.68166314	0.01310891		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.083494	162.2878	0.11449413	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.06209963	0.06209963	4.74	0.0341

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.06209963	0.06209963	4.74	0.0341

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|
INTERCEPT	0.1028685001	4.78	0.0001
FEE_PCT	-.0142868861	-2.18	0.0341

1

General Linear Models Procedure

Number of observations in data set = 58

1

General Linear Models Procedure

Dependent Variable: DD_PCT REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.01686986	0.01686986	1.21	0.2770
Error	52	0.72689291	0.01397871		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.022682	167.5855	0.11823159	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEE_PC*FEE_PC*FEE_PC	1	0.01686986	0.01686986	1.21	0.2770

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEE_PC*FEE_PC*FEE_PC	1	0.01686986	0.01686986	1.21	0.2770

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.0754481342	4.52	0.0001	0.01669565
FEE_PC*FEE_PC*FEE_PC	-.0000592562	-1.10	0.2770	0.00005394

1

General Linear Models Procedure

Number of observations in data set = 58

1

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.02767276	0.02767276	2.01	0.1623
Error	52	0.71609001	0.01377096		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.037206	166.3355	0.11734974	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEE_PCT*FEE_PCT	1	0.02767276	0.02767276	2.01	0.1623

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEE_PCT*FEE_PCT	1	0.02767276	0.02767276	2.01	0.1623

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.0798780484	4.62	0.0001	0.01727189
FEE_PCT*FEE_PCT	-.0008676277	-1.42	0.1623	0.00061205

1

General Linear Models Procedure

Number of observations in data set = 58

1

General Linear Models Procedure

Dependent Variable: DD_PCT REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.08970355	0.04485178	3.50	0.0377
Error	51	0.65405922	0.01282469		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.120608	160.5189	0.11324615	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.06209963	0.06209963	4.84	0.0323
FEE_PC*FEE_PC*FEE_PC	1	0.02760392	0.02760392	2.15	0.1485

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.07283369	0.07283369	5.68	0.0209
FEE_PC*FEE_PC*FEE_PC	1	0.02760392	0.02760392	2.15	0.1485

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.1269859087	4.72	0.0001	0.02689668
FEE_PCT	-.0303882632	-2.38	0.0209	0.01275156
FEE_PC*FEE_PC*FEE_PC	0.0001488709	1.47	0.1485	0.00010147

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.10896478	0.03632159	2.86	0.0460
Error	50	0.63479799	0.01269596		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.146505	159.7113	0.11267635	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.06209963	0.06209963	4.89	0.0316
FEE_PC*FEE_PC*FEE_PC	1	0.02760392	0.02760392	2.17	0.1466
FEE*FEE*FEE*FEE*FEE_	1	0.01926123	0.01926123	1.52	0.2238

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.07849486	0.07849486	6.18	0.0163
FEE_PC*FEE_PC*FEE_PC	1	0.02966431	0.02966431	2.34	0.1327
FEE*FEE*FEE*FEE*FEE_	1	0.01926123	0.01926123	1.52	0.2238

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.1490878209	4.63	0.0001	0.03222047
FEE_PCT	-.0488896712	-2.49	0.0163	0.01966207
FEE_PC*FEE_PC*FEE_PC	0.0006945243	1.53	0.1327	0.00045436
FEE*FEE*FEE*FEE*FEE_	-.0000029812	-1.23	0.2238	0.00000242

General Linear Models Procedure

Number of observations in data set = 58

General Linear Models Procedure

Dependent Variable: DD_PCT REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.13610598	0.04536866	3.73	0.0169
Error	50	0.60765679	0.01215314		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.182996	156.2597	0.11024126	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.06209963	0.06209963	5.11	0.0282
FEE_PCT*FEE_PCT	1	0.04154035	0.04154035	3.42	0.0704
FEE_PC*FEE_PC*FEE_PC	1	0.03246599	0.03246599	2.67	0.1084

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEE_PCT	1	0.08292102	0.08292102	6.82	0.0119
FEE_PCT*FEE_PCT	1	0.04640243	0.04640243	3.82	0.0563
FEE_PC*FEE_PC*FEE_PC	1	0.03246599	0.03246599	2.67	0.1084

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.1890832444	4.59	0.0001	0.04117626
FEE_PCT	-.1054490283	-2.61	0.0119	0.04036960
FEE_PCT*FEE_PCT	0.0177388121	1.95	0.0563	0.00907817
FEE_PC*FEE_PC*FEE_PC	-.0008554250	-1.63	0.1084	0.00052337

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.35624337	0.35624337	47.80	0.0001
Error	52	0.38751940	0.00745230		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.478974	122.3624	0.08632668	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.35624337	0.35624337	47.80	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.35624337	0.35624337	47.80	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-.0161904882	-0.94	0.3505	0.01718718
REV_FEE	0.0917136001	6.91	0.0001	0.01326494

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General Linear Models Procedure

Number of observations in data set = 54

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General Linear Models Procedure

Dependent Variable: DD_PCT REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.49305409	0.49305409	102.27	0.0001
Error	52	0.25070868	0.00482132		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.662918	98.42055	0.06943573	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REV_FEE*REV_FEE	1	0.49305409	0.49305409	102.27	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REV_FEE*REV_FEE	1	0.49305409	0.49305409	102.27	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.0280183136	2.71	0.0091	0.01034275
REV_FEE*REV_FEE	0.0253346227	10.11	0.0001	0.00250524

1 17

General Linear Models Procedure

Number of observations in data set = 58

1 18

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.51036733	0.25518367	55.76	0.0001
Error	51	0.23339544	0.00457638		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.686196	95.88791	0.06764896	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.35624337	0.35624337	77.84	0.0001
REV_FEE*REV_FEE	1	0.15412396	0.15412396	33.68	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.01731324	0.01731324	3.78	0.0573
REV_FEE*REV_FEE	1	0.15412396	0.15412396	33.68	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	0.0584926522	3.14	0.0028	0.01862836
REV_FEE	-.0523453897	-1.95	0.0573	0.02691227
REV_FEE*REV_FEE	0.0366717056	5.80	0.0001	0.00631913

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.61314218	0.20438073	78.23	0.0001
Error	50	0.13062059	0.00261241		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.824379	72.44753	0.05111176	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.35624337	0.35624337	136.37	0.0001
REV_FEE*REV_FEE	1	0.15412396	0.15412396	59.00	0.0001
REV_FE*REV_FE*REV_FE	1	0.10277485	0.10277485	39.34	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.05726397	0.05726397	21.92	0.0001
REV_FEE*REV_FEE	1	0.06324443	0.06324443	24.21	0.0001
REV_FE*REV_FE*REV_FE	1	0.10277485	0.10277485	39.34	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-.0325532892	-1.61	0.1137	0.02021876
REV_FEE	0.2339455392	4.68	0.0001	0.04996833
REV_FEE*REV_FEE	-.1425072415	-4.92	0.0001	0.02896320
REV_FE*REV_FE*REV_FE	0.0259348094	6.27	0.0001	0.00413486

General Linear Models Procedure

Dependent Variable: DD_PCT   REAL COST OF DESIGN DEFICIENCYPER PROJEC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.63229707	0.21076569	94.54	0.0001
Error	50	0.11146570	0.00222931		
Corrected Total	53	0.74376277			

R-Square	C.V.	Root MSE	DD_PCT Mean
0.850133	66.92500	0.04721561	0.07055003

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.35624337	0.35624337	159.80	0.0001
REV_FE*REV_FE*REV_FE	1	0.19365438	0.19365438	86.87	0.0001
REV*REV*REV*REV*REV_	1	0.08239932	0.08239932	36.96	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REV_FEE	1	0.05001364	0.05001364	22.43	0.0001
REV_FE*REV_FE*REV_FE	1	0.04204844	0.04204844	18.86	0.0001
REV*REV*REV*REV*REV_	1	0.08239932	0.08239932	36.96	0.0001

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	-.0029072715	-0.21	0.8366	0.01402490
REV_FEE	0.0986361512	4.74	0.0001	0.02082464
REV_FE*REV_FE*REV_FE	-.0155257005	-4.34	0.0001	0.00357488
REV*REV*REV*REV*REV_	0.0007302215	6.08	0.0001	0.00012011